



**8<sup>th</sup> INTERNATIONAL MULTIDISCIPLINARY SCIENTIFIC SYMPOSIUM**

## **UNIVERSITARIA SIMPRO 2018**

*11-13 OCTOBER 2018, PETROȘANI*



***CONFERENCE PROCEEDINGS***

**Editor: Roland Iosif MORARU**

**E-editors: Csaba LORINȚ**

**Radu ION**

## **DISCLAIMER**

This book contains abstracts and complete papers approved by the Conference Reviewers and Committees. Authors are responsible for the content and accuracy.

Information in the SIMPRO 2018 Conference Proceedings is subject to change without notice. No part of this book may be reproduced or transmitted in any form or by any means, for any purpose, without the express written permission of the International Multidisciplinary Scientific Symposium Editors and the Chairman of SIMPRO 2018.

Copyright ©SIMPRO 2018

All Rights Reserved by the International Multidisciplinary Scientific Symposium Published by Universitas Publishing House, Universității str., no 20, 332006 Petrosani.

Total print: 100.

**ISSN–L 1842 – 4449**

**ISSN 2344 – 4754**

**INTERNATIONAL MULTIDISCIPLINARY SCIENTIFIC SYMPOSIUM UNIVERSITARIA**

**SIMPRO, Secretariat Bureau**

Phone + 4 025 454 6112

Fax + 4 025 454 6112

E-mail [simpro@upet.ro](mailto:simpro@upet.ro)

URL [www.upet.ro/simpro/2018/](http://www.upet.ro/simpro/2018/)



## **ORGANIZERS:**

UNIVERSITY OF PETROȘANI & NIRD - INSEMEX PETROȘANI

## **Under the auspices:**

ACADEMY OF ROMANIAN SCIENTISTS

ACADEMY OF TECHNICAL SCIENCES OF ROMANIA

MINISTRY OF NATIONAL EDUCATION

GENERAL ASSOCIATION OF ENGINEERS IN ROMANIA, AGIR

## **In partnership with\*:**

ALUMNI ASSOCIATION OF THE UNIVERSITY OF PETROȘANI,

AMEROPA GRAINS S.A. ROMANIA, CONSTANȚA

ASSYSTEM TECHNOLOGIES ROMANIA

„AUREL VLAICU” UNIVERSITY OF ARAD

CDPM UNION

CHIMPEX CONSTANȚA

CZESTOCHOWA UNIVERSITY OF TECHNOLOGY

HUNEDOARA COUNTY COUNCIL

LABOUR INSPECTORATE

MOL ROMÂNIA

NATIONAL AUTHORITY FOR SCIENTIFIC RESEARCH

OPOLE UNIVERSITY OF TECHNOLOGY

S.C. GLOBAL CONSULTING S.R.L. TOPOLOVENI

SOCIETATEA NAȚIONALĂ A SĂRII, SALROM

SSM-SIU S.R.L. TÂRGU-MUREȘ

---

\* Alphabetically ordered

## **COMMITTEE MEMBERS:**

### **ORGANISING COMMITTEE**

#### **CONFERENCE CHAIR**

Prof. dr. Roland Iosif MORARU, University of Petroșani, ROMANIA

#### **HONORARY PRESIDENT**

Prof. dr. Sorin–Mihai RADU, University of Petroșani, ROMANIA

#### **CO-CHAIRS**

Assoc. Prof. dr. Codruța DURA, University of Petroșani, ROMANIA

Dr. George Arthur GĂMAN, INCD-INSEMEX Petroșani, ROMANIA

Prof. dr. Eduard EDELHAUSER, University of Petrosani, ROMANIA

#### **MEMBERS**

Imola DRIGĂ, ROMANIA, Andreea Cristina IONICĂ, ROMANIA

Iosif DUMITRESCU, ROMANIA, Mihaela TODERAȘ, ROMANIA

Ion DOȘA, ROMANIA, Maria DOBRIȚOIU, ROMANIA

#### **INTERNATIONAL SCIENTIFIC COMITEE**

Tatiana ANTIPOVA, Institute of Certified Specialists, Perm, RUSSIA

Umer ASGHER, National Institute of Science and Technology, Islamabad, PAKISTAN

Constantin BACIU, Technical University “Gh. Asachi” of Iași, ROMANIA

Lia Alexandra BALTADOR, “Lucian Blaga”, University of Sibiu, ROMANIA

Radian G. BELU, Southern University and A&M College, Baton Rouge, U.S.A.

Daniel BREAZ, “1 Decembrie 1918”, University of Alba-Iulia, ROMANIA

Daniela BUZOIANU, University of Oil and Gasses, Ploiești, ROMANIA

Amir CAUSEVIC, University of Sarajevo, BOSNIA-HERZEGOVINA

Lucian-Ionel CIOCA, “Lucian Blaga” University of Sibiu, ROMANIA

Mihai Pascu COLOJA, University of Oil and Gasses, Ploiești, ROMANIA

Doru Costin DARABONT, NIRD-INCDPM Bucharest, ROMANIA

Predrag DASIC, High Technical Mechanical School of Professional Studies Trstenik, SERBIA

Anca DRĂGHICI, “POLITEHNICA” University of Timișoara, ROMANIA

Carsten DREBENSTEDT, TU Bergakademie, Freiberg, GERMANY

George Artur GĂMAN - NIRD INSEMEX Petroșani, ROMANIA

Emilian GHICIOI, NIRD INSEMEX Petroșani, ROMANIA  
Janusz GRABARA, Czestochowa University of Technology, POLAND  
Valentin RĂILEAN, IMI-NOVA, MOLDOVA  
Claudiu KIFOR, “Lucian Blaga” University of Sibiu, ROMANIA  
Karoly KOCSIS, College of Sciences, Mackay School of Earth Sciences and Engineering,  
University of Nevada, Reno, USA  
Gábor LADÁNYI, University of Miskolc, HUNGARY  
Omar LANCHAVA, Georgian Technical University, GEORGIA  
Ramona LILE, „Aurel Vlaicu” University of Arad  
József MOLNÁR, University of Miskolc, HUNGARY  
Mariana NAGY, „Aurel Vlaicu” University of Arad  
Sonia PAVLOVICI-VESELINOVICI, University of Niš, SERBIA  
Daniel PUPĂZAN, NIRD INSEMEX Petroșani, ROMANIA  
Elena Cristina RADA, Università dell’Insubria di Varese, ITALY  
Marco RAGAZZI, Università degli Studi di Trento, ITALY  
Krzysztof KRAUZE, AGH University of Science and Technology, POLAND  
Abd alBadi Mohammed Mahmoud SALEM, AinShams University, Cairo, EGYPT  
Biplap Xanthi SENGUPTA, Kharagpur Indian Institute of Technology, INDIA  
Semion SHKUNDIN, University NITU "MISIS" Moscova, RUSSIA  
Krysztyna SKIBNIEWSKA, University of Warmia and Mazury in Olsztyn, POLAND  
Vincenzo TORRETTA, Università dell’Insubria di Varese ITALY  
Lyuben TOTEV, University of Mining and Geology “Ivan Rilski”, Sofia, BULGARIA  
Dumitru ȚUCU, “POLITEHNICA” University of Timișoara Timișoara, ROMANIA  
Jean-Jacques WAGNER, IUT de Belfort-Montbéliard, FRANCE  
Janusz WIELKI, Politechnika Opolska, POLAND

## **NATIONAL SCIENTIFIC COMMITTEE**

Ioan BUD – Universitatea Tehnica Cluj Napoca, Centrul de Nord, Baia Mare

Prof. dr. ing. Sabina IRIMIE – Universitatea din Petroșani

Prof. dr. mat. Wilhelm W. KECS – Universitatea din Petroșani

Prof. dr. ing. Maria LAZĂR – Universitatea din Petroșani

Prof.dr.ing. Monica LEBA – Universitatea din Petroșani

Prof. dr. ec. Mariana MAN – Universitatea din Petroșani

Prof. dr. ing. Gheorghe MANOLEA – Universitatea din Craiova

Prof.dr.ing. Dan Codrut PETRILEAN – Universitatea din Petroșani

Conf.dr.ing. Gabriel BĂBUȚ – Universitatea din Petroșani

Conf.dr. Gabriela DUMBRAVĂ – Universitatea din Petroșani

Conf. dr.ing.Csaba LORINȚ – Universitatea din Petroșani

Conf.dr.ing. Ioel VEREȘ – Universitatea din Petroșani

Șef lucr. dr.ing. Ladislau RADERMACHER – Universitatea din Petroșani

Lector.dr. Mihaela SCHMIDT – Universitatea din Petroșani

## **ADVISORY BOARD**

Nicolae DIMA, ROMANIA, Nicolae ILIAS, ROMANIA

Dumitru FODOR, ROMANIA, Mircea GEORGESCU, ROMANIA

Iozsef KOVACS, ROMANIA, Andrei MAGYARI, ROMANIA

Emil POP, ROMANIA, Dorel ZUGRAVESCU, ROMANIA

## **SECRETARIES OF SESSIONS**

Assoc. Prof. dr.eng. Larisa FILIP

Assoc. Prof. dr. ec. Mirela MONEA

Assoc. Prof. dr. eng. Dragoș PĂSCULESCU

Assoc. Prof. dr. eng. Mihaela GHICAJANU

Lecturer dr. eng. Stela DINESCU

Lecturer dr. eng. Florin FAUR

Lecturer dr. geogr. Ciprian NIMARĂ

Lecturer dr. eng. Florin G. POPESCU

Lecturer dr. eng. Mihai POPESCU-STELEA

Lecturer dr. Laura MARICA

Lecturer dr. Lavinia HULEA

## REVIEWERS

Gabriel Bujor BĂBUȚ

Ioan BUD

Angela CĂLĂMAR

Doru CIOCLEA

Diana CSIMINGA

Stela DINESCU

Marian DACIAN

Emilia DUNCA

Codruța DURA

Imola DRIGĂ

Angela EGRI

Adrian FLOREA

Carmen FLOREA

Larisa FILIP

Artur GĂMAN

Mircea GEORGESCU

Mihaela GHICAJANU

Emilian GHICIOI

Andreea IONICĂ

Sabina IRIMIE

Claudia ISAC

Maria LAZĂR

Monica LEBA

Mariana MAN

Gheorghe MANOLEA

Marius MARCU

Marin Silviu NAN

Ilie ONICA

Dragoș PĂSCULESCU

Nicolae PATRĂȘCOIU

Dan Codruț PETRILEAN

Roxana PLEȘA

Mihai POPESCU-STELEA

Florin Dumitru POPESCU

Florin Gabriel POPESCU

Oana RĂVAȘ

Mihaela SCHMIDT

Olimpiu STOICUȚA

Mihaela TODERAȘ

Eugen TRAISTĂ

Ioel VEREȘ



# CONTENTS

<b>SECTION 1.</b>		
<b>ADVANCES IN SAFETY SCIENCE AND OCCUPATIONAL RISK MANAGEMENT</b>		
1	Guram Abashidze, Nicolae Ilias, Roland Moraru, David Tsverava <i>THE POSSIBILITY OF SAFETY IMPROVEMENT THROUGH EXOGENOUS FIRE PREDICTION IN MINE WORKINGS AND TRANSPORT TUNNELS</i>	<b>21</b>
2	Omar Lanchava, Nicolae Ilias, Giorgi Nozadze, Sorin Radu <i>HEAT AND HYGROSCOPIC MASS EXCHANGE MODELING FOR SAFETY MANAGEMENT IN TUNNELS OF METRO</i>	<b>27</b>
3	Giorgi Nozadze <i>DYNAMICS OF SPREAD OF FIRE-RELATED HARMFUL FACTORS IN METRO TUNNELS DURING A FORCED STOPPAGE OF THE METRO TRAIN</i>	<b>33</b>
4	Nicolae Bancila-Afrim, Roland Iosif Moraru, Lucian - Ionel Cioca, Gabriel Bujor Babut <i>ACCIDENTS AT WORK AMONG INDUSTRIAL PRESSES OPERATORS: ANALYSIS OF STATISTICS IN NORTH-WESTERN REGION OF ROMANIA</i>	<b>39</b>
5	Vlad Mihai Păsculescu, Emilian Ghicioi, Marius Simion Morar, Dragoș Păsculescu, Marius Cornel Șuvar <i>COMPUTATIONAL STUDY FOR IMPROVING THE QUALITY OF SAFETY MEASURES FOR LPG FILLING STATIONS</i>	<b>45</b>
6	Mihaela Laura Bratu, Lucian-Ionel Cioca <i>MANAGERIAL STRATEGIES FOR OPTIMIZING ERGONOMICS IN ORGANIZATIONS, TAILORED TO THE PERSONALITY OF ENGINEERS, TO IMPROVE THE QUALITY OF LIFE AND SECURITY OF EMPLOYEES</i>	<b>51</b>
7	Nicolae Daniel Fiță, Dragoș Păsculescu, Roland Moraru <i>IDENTIFICATION OF RISK SCENARIOS ON CRITICAL INFRASTRUCTURES OF ULTRA HIGH AND VERY HIGH VOLTAGE FOR THE PURPOSE OF RISK ASSESSMENT AND QUALITY IMPROVEMENT OF THE NATIONAL POWER GRID</i>	<b>57</b>
8	Marius Cornel Suvar, Emilian Ghicioi, Laurențiu Munteanu, Vlad Mihai Păsculescu, Gheorghe Daniel Florea, Niculina Sonia Suvar, Aurelian Nicola <i>COMPUTATIONAL STUDY ON THE QUALITY OF THE SUPPRESSION EFFECT OF SPRINKLERS ON BUILDING FIRES SPREAD AND INTERACTION WITH SMOKE LAYERS</i>	<b>63</b>
9	Ilie-Ciprian Jitea, Dragos Gabriel Vasilescu, Robert Laszlo, Cristian Raul Cioara, Claudia Miron <i>IMPROVING THE QUALITY FOR CLASSIFICATION OF PYROTECHNIC ARTICLES ON THE BASIS OF PYROTECHNIC COMPOSITION CONTENT</i>	<b>69</b>
10	Dragos Gabriel Vasilescu, Robert Laszlo, Attila Kovacs, Cristian Radeanu, Olga Miclea <i>PROSPECTIVE AND EXPLORATORY RESEARCH IN THE QUALITY FIELD OF INDUSTRIAL RISK ASSESSMENT AND ANALYSIS</i>	<b>75</b>
11	Izabella Kovacs, Daniel Pupăzan, Cristian Nicolescu, Alin Irimia, Andrei Gireadă, Cosmin Ilie <i>RESEARCH ON PSYCHOLOGICAL INDICATORS INVOLVED IN RESCUE ACTIVITIES</i>	<b>81</b>
12	Marius Darie, Sorin Burian, Tiberiu Csaszar, Cosmin Colda, Dănuț Grecea <i>CONSIDERATIONS ON LOW CURRENT CIRCUITS PROFICIENCY TESTS WITH EXPLOSIVE GAS MIXTURES</i>	<b>87</b>
13	Cristian Tomescu, Doru Cioclea, Ion Gherghe, Emeric Chiuzean, Marius Morar <i>DETERMINATION OF DANGER, RISK AND FIRE VULNERABILITY PARAMETERS. NUMERICAL SIMULATION IN FIRE EXTINCTION</i>	<b>93</b>
14	Gireada Andrei-Lucian, Găman George Artur, Nicolescu Cristian, Ilie Cosmin, Irimia Alin, Kovacs Izabella <i>RESEARCH ON ESTABLISHING THE PHYSICAL EFFORT OF RESCUERS ACCORDING TO THE ACTIVITY PERFORMED AND TYPE OF RESPIRATION PROTECTION EQUIPMENT</i>	<b>99</b>
15	Alin Irimia, Sorin Burian, Florin Păun, Dan Gabor, Marius Darie <i>TESTING THE TEMPERATURE PROOF OF SELF-CONTAINED BREATHING APPARATUS, BASED ON COMPRESSED AIR</i>	<b>105</b>
16	Sorin Simion, Marius Kovacs, Lorand Toth, Alexandru Simion, Maria Badescu <i>MONITORING WORKER'S EXPOSURE TO PHYSICOCHEMICAL POLLUTANTS TO PREVENT OCCUPATIONAL ILLNESS</i>	<b>109</b>

17	Costica Bejinariu, Diana-Petronela Burduhos-Nergis, Nicanor Cimpoesu, Mihai-Adrian Bernevig-Sava, Stefan-Lucian Toma, Doru-Costin Darabont, Constantin Baci <i>STUDY ON THE ANTICORROSIVE PHOSPHATED STEEL CARABINERS USED AT PERSONAL PROTECTIVE EQUIPMENT</i>	<b>113</b>
18	Diana-Petronela Burduhos-Nergis, Carmen Nejneru, Ramona Cimpoesu, Alin-Marian Cazac, Constantin Baci, Doru-Costin Darabont, Costica Bejinariu <i>ANALYSIS OF CHEMICALLY DEPOSITED PHOSPHATE LAYER ON THE CARABINERS STEEL SURFACE USED AT PERSONAL PROTECTIVE EQUIPMENT</i>	<b>119</b>
19	Cristian Rădeanu, Attila Kovacs, Daniela Rus, Ilie - Ciprian Jitea, Dragos Gabriel Vasilescu <i>INCREASE IN THE SECURITY QUALITY IN USE OF PROFESSIONAL PYROTECHNIC ARTICLES FALLING IN CATEGORY F4</i>	<b>125</b>
20	Cosmin Ilie, Daniel Pupăzan, Cristian Nicolescu, Alin Irimia, Andrei Gireadă, Izabella Kovacs <i>RESEARCHES ON THE DEVELOPMENT OF SPECTROSCOPY TECHNOLOGY USED IN THE PROCESS OF PRESSURE NETWORKS TECHNICAL VERIFICATION</i>	<b>131</b>
21	Daniela Carmen Rus, Emilian Ghicioi, Robert Laszlo, Cristian Rădeanu, Attila Kovacs, Gabriel Vasilescu <i>ASSESSING THE QUALITY SAFETY PERFORMANCE OF THE DEFLAGRATION - DETONATING TRANSIENT BEHAVIOR SPECIFIC TO CLASS 1 HAZARDOUS MATERIALS, ACCORDING TO ORANGE BOOK</i>	<b>137</b>
22	Edward Gheorghiosu, Emilian Ghicioi, Robert Laszlo, Attila Kovacs, Cristian Rădeanu, Dan Gabor <i>CHECKING THE QUALITY OF THE ELECTRIC IGNITER - PYROTECHNIC ARTICLE OF CATEGORY P1, BY LABORATORY METHODS APPLIED TO DETERMINE THE SENSITIVITY TO ELECTROSTATIC DISCHARGE</i>	<b>141</b>
23	Gheorghe - Daniel Florea, Nicolae - Ioan Vlasin, Zoltan Vass, Bogdan Adrian Șimon, Ligia Ioana Tuhuț <i>COMPUTATIONAL SIMULATIONS OF THE TRANSPORT AND IGNITION OF METHANE IN ENCLOSED SPACES</i>	<b>145</b>
24	Szollosi- Mota Andrei, Ghicioi Emilian, Prodan Maria, Nalboc Irina, Suvar Sonia <i>DETERMINATION OF FLAMMABILITY PARAMETERS AND BURNING GASES, IN ORDER TO REDUCE RISKS IN THE FIRE OR EXPLOSION TYPE EVENTS</i>	<b>151</b>
25	Dan Gabor, Sorin Mihai Radu, Emilian Ghicioi, Mihaela Paraian, Adrian Marius Jurca, Niculina Vatavu, Florin Paun, Catalin Mihai Popa <i>STUDY OF METHODS FOR ASSESSMENT OF THE IGNITION RISK OF DUST/AIR EXPLOSIVE ATMOSPHERES BY ELECTROSTATIC DISCHARGE</i>	<b>157</b>
26	Niculina-Sonia Șuvar, Emilian Ghicioi, Irina Nălboc, Andrei Szollosi-Moța, Maria Prodan <i>IDENTIFICATION OF BURNING ACCELERATORS IN INVESTIGATION OF FIRES USING THE INFRARED SPECTROSCOPY METHOD (FTIR)</i>	<b>163</b>
27	Lorand Toth, George Artur Găman, Angelica Călămar, Daniel Pupăzan, Cristian Nicolescu, Izabella Kovacs <i>ELEMENTS OF DISASTER MANAGEMENT AND FIRST AID</i>	<b>169</b>
28	Anisoara Corabieru, Elena Mihalache, Mihai - Adrian Bernevig - Sava, Nicoleta - Monica Lohan <i>PIPE MANUFACTURING PROCESS NOISE AND VIBRATION DETERMINATION CASE STUDY</i>	<b>175</b>
29	Doru Costin Darabont, Costica Bejinariu, Constantin Baci, Mihai-Adrian Bernevig-Sava <i>MODERN APPROACHES IN INTEGRATED MANAGEMENT SYSTEMS OF QUALITY, ENVIRONMENTAL AND OCCUPATIONAL HEALTH AND SAFETY</i>	<b>181</b>
30	Paul Ciubotariu - Ana, Mihai - Adrian Bernevig - Sava, Nicoleta - Monica Lohan, Costică Bejinariu <i>STUDY ON INCREASING THE THERMAL PROTECTION OF HIGH-TEMPERATURE HELMETS USED BY FIREFIGHTERS</i>	<b>185</b>
31	Mihai-Adrian Bernevig-Sava, Doru Costin Darabont, Nicoleta Monica Lohan, Elena Mihalache, Costica Bejinariu <i>SELECTION AND VERIFICATION OF PERSONAL PROTECTIVE EQUIPMENT IN THE CONTEXT OF CURRENT LEGAL REQUIREMENTS</i>	<b>191</b>
32	Constantin Baci, Costica Bejinariu, Doru Costin Darabont, Anisoara Corabieru, Mihai-Adrian Bernevig-Sava <i>OCCUPATIONAL SAFETY AND HEALTH AUDIT BETWEEN THEORY, LEGAL REQUIREMENTS AND PRACTICE</i>	<b>195</b>



33	Andrian Batugin, Konstantin Kolikov, Alexander Ivannikov <i>TRANSFORMATION OF THE GEODYNAMIC HAZARD MANIFESTATION FORMS IN MINING AREAS</i>	199
34	Florina Luminita Besnea, Stefan-Irinel Cismaru, Nicu-George Bizdoaca <i>OPERATING ENVIRONMENT IN AUGMENTED REALITY MAINTENANCE APPLICATIONS</i>	205
35	Joanna Tabor <i>APPLICATION THE FUZZY TOPSIS METHOD TO ASSESS AND SELECT A CONTRACTOR FROM THE POINT OF VIEW OF OCCUPATIONAL SAFETY MANAGEMENT</i>	209
36	George Danko <i>LIMITATIONS AND ERROR MITIGATION FOR MINE CLIMATE MODELS WITH NO THERMAL HISTORY COMPONENT</i>	215
37	Zerbes Mihai-Victor, Cioca Lucian-Ionel, Neamu Vasilica-Silvia <i>DEVELOPING A MODEL OF OCCUPATIONAL HEALTH PROGRAM</i>	221
38	Zerbes Mihai-Victor, Cioca Lucian-Ionel, Neamu Vasilica-Silvia <i>OCCUPATIONAL HEALTH PROGRAMS AND WORKPLACE ABSENTEEISM</i>	227
39	Bianca Cirjaliu, Anca Mocan, Boatca Maria - Elena, Anca Draghici <i>A PROPOSE APPROACH FOR CONTINUOUS IMPROVEMENT USING ERGONOMICS AND QUALITY MANAGEMENT KNOWLEDGE AND METHODOLOGIES</i>	233
40	Alin Gaureanu, Anca Draghici, Hugo Weinschrott <i>INCREASING THE QUALITY OF OCCUPATIONAL SAFETY AND HEALTH IMPLEMENTATIONS THROUGH AWARENESS TRAINING FOR THOSE INVOLVED IN IMPLEMENTING THE SAFETY OBSERVATION REPORT</i>	239
41	Nicoleta Craciun, Alina Trifu <i>REDUCING THE RISK OF SLIPPING ON ICE BY SELECTING APPROPRIATE PROTECTIVE FOOTWEAR</i>	245
42	Gabriel Bujor Băbuț, Roland Iosif Moraru <i>MANAGING THE ACTIVITIES OF AUTHORIZATION TO PRACTICE TRADES AND PROFESSIONS IN TERMS OF SAFETY AND HEALTH AT WORK</i>	251
43	Gabriel Bujor Băbuț, Roland Iosif Moraru, Popescu Stelea Mihai, Babut Andrada Denisa <i>IMPROVING DRAINED GAS QUALITY PARAMETERS THROUGH OPTIMAL MANAGEMENT OF METHANE DRAINAGE SYSTEMS</i>	257
44	Georgeta Buica, Antonov Anca Elena, Constantin Beiu, Dragos Pasculescu, Mircea Risteiu <i>MANAGEMENT OF ELECTRICAL EQUIPMENT AND PROTECTIVE DEVICES USED IN ELECTRICAL INSTALLATIONS</i>	263
46	Radu Mares, Mihai Popescu - Stelea, Roland Iosif Moraru, Gabriel Bujor Băbuț, Mariana Nagy <i>EMPLOYEES PROTECTION IN MAINTENANCE ACTIVITIES. A STATISTIC IMAGE</i>	269
46	Anca Elena Antonov, Georgeta Buicaa, Constantin Beiu, Raluca Aurora Stepa <i>MANAGEMENT OF DANGEROUS SUBSTANCES RELEASED BY MACHINERY, CONDITION TO ENSURE SAFETY AND WORKERS' HEALTH AND ENVIRONMENTAL</i>	275
<b>SECTION 2.</b>		
<b>CHALLENGES IN MINING ENGINEERING, SURVEYING AND CIVIL ENGINEERING</b>		
1	Emeric Chiuzean, George Artur Gaman, Cristian Tomescu, Adrian Matei, Razvan Dragoescu <i>ANALYSIS OF THE METHODS OF EXPLOITATION APPLIED TO ROMANIAN SALT MINES</i>	281
2	Marius Simion Morar, Doru Cioclea, Cristian Raul Cioara, Vlad Mihai Pasculescu <i>UNDERGROUND ENVIRONMENT OPTIMIZATION USING SPECIALIZED PROGRAMS</i>	287
3	Bușe Florian, Bușe Gheorghe Florin <i>THE IMPACT OF THE INTEGRATED TECHNICAL SYSTEM ON THE QUALITY OF CONSTRUCTION WORKS</i>	293
4	Florin Rădoi, Ion Gherghe, Emeric Chiuzean, Adrian Matei, Răzvan Drăgoescu <i>EFFICIENCY OF INDUSTRIAL VENTILATION INSTALLATIONS</i>	299
5	Kovacs Attila, Ghiciei Emilian, Laszlo Robert, Dinu Florea, Jitea Ciprian Ilie <i>ANALYSIS OF THE BEHAVIOR OF METALLIC STRUCTURES OF MULTI-LEVEL BUILDINGS WHEN EXPOSED TO DYNAMIC EFFECTS DUE TO EXPLOSIVE DETONATION</i>	303
6	Adrian Matei, Răzvan Drăgoescu, Doru Cioclea, Emeric Chiuzean, Florin Radoi <i>ANALYSIS OF EXPLOSIVE ENVIRONMENTS THAT INTERACTS WITH INDUSTRIAL VENTILATION SYSTEMS</i>	309

7	Doru Cioclea, Nicolae Ianc, Marius Morar, Adrian Matei, Răzvan Drăgoescu <i>EFFICIENCY OF COMPLEX VENTILATION NETWORKS</i>	315
8	Laszlo Robert, Gheorghiosu Edward, Vasilescu Dragos Gabriel, Kovacs Attila, Jitea Ciprian, Galvitu Mihaela <i>INCREASING THE SAFETY, QUALITY AND EFFICIENCY OF DEMOLITION / DISMANTLING OF METAL STRUCTURES BY USING BLASTING WORKS</i>	321
9	Ion Gherghe, Doru Cioclea, Cristian Tomescu, Florin Rădoi, Corneliu Boantă, Emeric Chiuzean <i>FANS, SPECIFIC OPERATIONAL PARAMETERS OF INDUSTRIAL VENTILATION INSTALLATIONS</i>	327
10	Ianc Nicolae, Cioclea Doru, Gherghe Ion, Radoi Florin, Chiuzean Emeric, Matei Adrian, Dragoescu Razvan <i>THE IMPACT ON THE ENVIRONMENT PRODUCED BY THE METHANE GAS RELEASED IN THE JIU VALLEY COAL MINES</i>	333
11	Karoly Charles Kocsis, Roghanchi Pedram, Teixeira B. Marcelo, Parrish Jacob, Scalise Kyle <i>SENSITIVITY ANALYSIS ON MAJOR HEAT SOURCES AND EVALUATION OF COOLING SYSTEMS TO PROVIDE ADEQUATE WORK CONDITIONS IN UNDERGROUND METAL MINES</i>	339
12	Jozsef Molnar, Ákos Debreczeni, Richárd Tompa. <i>CHALLENGES AND OPPORTUNITIES OF UNDERGROUND COAL MINING IN NORTH-EASTERN HUNGARY</i>	347
13	Gelu Madear, Camelia Madear <i>PROBABILISTIC APPROACHES IN TUNNEL DESIGN</i>	353
14	Gelu Madear, Camelia Madear <i>LOADS ESTIMATION IN BLOCK CAVING MINING</i>	359
15	S.A. Lutsenko, S.A. Zhukov <i>PLANNING THE DEVELOPMENT OF MINING OPERATIONS UNDER THE CHANGING DEMAND FOR IRON ORE PRODUCTS</i>	365
16	Toderas Mihaela, Danciu Ciprian <i>ASSESSMENT METHODOLOGY OF INSTANTANEOUS ELASTIC DEFORMATION OF SEDIMENTARY ROCKS</i>	371
17	Filip Larisa <i>THE DEVELOPMENT OF MINERAL TRIANGULATION NETWORKS USING A SIMPLIFIED CALCULATION PROCESS</i>	377
18	Zhukov S.A., Skachkov A.A., Titov D.A. <i>IMPROVEMENT OF BLASTING OPERATIONS IN OPEN PIT BY DIFFERENTIAL STRAIN AND SYMMETRICAL BLASTING OF THE ROCK</i>	381
19	Danciu Ciprian, Toderas Mihaela, Lorint Csaba, Florea Adrian <i>CHARACTERIZATION AND CLASSIFICATION OF ANDESITES OF CRISCIOR AND ALBINI FROM SOUTHERN APUSENI MOUNTAINS, FOR CAPITALIZATION</i>	387

### **SECTION 3.**

#### **SUSTAINABLE ENVIRONMENTAL ENGINEERING AND PROTECTION**

1	Nikolay Savov, Teodora Hristova, Petya Gencheva <i>EXPLORING POSSIBLE ACCIDENTS AND RECOMMENDATIONS FOR BIOLOGICAL WASTE TREATMENT INSTALLATIONS</i>	393
2	Florin Adrian Paun, Mihaela Paraian, Adrian Marius Jurca, Dan Gabor, Niculina Vatavu, Catalin Mihai Popa <i>SELECTION OF PERSONAL PROTECTIVE EQUIPMENT FOR USE IN POTENTIALLY EXPLOSIVE ATMOSPHERES</i>	399
3	Cătălin Mihai Popa, Silviu Marin Nan, Mihaela Părăian, Adrian Marius Jurca, Florin Adrian Păun, Leonard Lupu, Niculina Vătavu, Dan Gabor <i>STUDY OF EXPLOSIVE CHARACTERISTICS OF COMBUSTIBLE POWDERS</i>	403
4	Niculina Vatavu, Emilian Ghicioi, Sorin Vatavu, Mihaela Paraian, Adrian Jurca, Florin Paun, Dan Gabor, Mihai Popa <i>RESEARCH ON THE IDENTIFICATION OF THE DANGERS OF DUST AND WATER ENTERING EQUIPMENT FOR POTENTIALLY EXPLOSIVE ATMOSPHERES</i>	409
5	Alexandru Florin Simion, Angelica Nicoleta Calamar, Lorand Toth, Marius Kovacs, Sorin Simion <i>RESEARCHES ON THE MACROELEMENTS CONTENT FROM JIU VALLEY COAL ASH</i>	415

6	Marius Kovacs, Angelica-Nicoleta Călămar, Lorand Toth, Sorin Simion, Alexandru Simion, Kovacs Izabella <i>OPPORTUNITY OF USING DRONES EQUIPPED WITH SENSORS FOR MEASUREMENT OF COMBUSTION GASES</i>	421
7	Maria Lazar <i>QUALITY OF THE ENVIRONMENT - THE RESULT OF THE INTERACTION BETWEEN TECHNOLOGICAL PROGRESS AND EDUCATION</i>	427
8	Andrei-Cristian Lupu, Marius Gabriel Petrescu <i>EQUIPMENT FOR WATER OZONIZATION IN FISH BREEDING PONDS</i>	433
9	Andrei-Cristian Lupu, Marius Gabriel Petrescu <i>PLANT FOR IMPROVING WATER QUALITY IN JUVENILE FISH PONDS</i>	437
10	Andrei-Cristian Lupu, Marius Gabriel Petrescu <i>MOBILE AUTONOMOUS AERATOR</i>	441
11	Roland Romend, Zoltán Virág, Tamás Magyar <i>MECHANICAL PROCESSING METHODS OF WASTE ELECTRONIC AND ELECTRICAL EQUIPMENT WITH SPECIAL REGARDS TO NIR SEPARATION</i>	445
12	Andreea Adriana Petcov, Camen Dorin, Moatăr Mihaela, Petolescu Cerasela, Turc Alina, Sasu Andreia <i>NITRITE CONTENT IN THE SAMPLES COLLECTED FROM IN LAND SURFACE WATERS IN GRADINARI VILLAGE</i>	449
13	Lucian-Ionel Cioca, Larisa Ivascu, Szilard Szekely <i>CHALLENGES AND OPPORTUNITIES ASSOCIATED WITH WASTE RECYCLING DEVELOPMENT IN ROMANIA</i>	453
14	Ileana-Sorina Rakos, Sorinel Căpușneanu, Dana-Maria (Oprea) Constantin, Dan Ioan Topor, Elena Bogan <i>IMPROVE AIR QUALITY MANAGEMENT BY MONITORING AND ASSESSING HEAVY METAL EMISSIONS. CASE STUDY: HUNEDOARA COUNTY, ROMANIA</i>	459
15	Pavla Hlavatá, Karla Meixnerová, Vladimír Horák, Jiří Kosek <i>INFLUENCE OF THERMAL CONDITIONS IN A QUARRY ON THE LOCAL CLIMATE.</i>	465
16	Faur Florin, Lazăr Maria, Nyari (Apostu) Izabela-Maria <i>SUBSTANTIATING THE DECISION REGARDING THE ECOLOGICAL RECONSTRUCTION OF MINING WASTE DUMPS - CASE STUDY FOR LUPENI DUMP</i>	471
17	Camelia Madear, Gelu Madear <i>CLAY LINER DESIGN OF A LANDFILL IN JIU VALLEY BASED ON DETERMINISTIC &amp; STOCHASTIC RISK ANALYSIS</i>	477
18	Camelia Madear, Gelu Madear <i>RISK-BASED REMEDIAL TARGETS FOR CONTAMINATED LAND</i>	483
19	Camelia Madear, Gelu Madear, Sorin Mihai Radu <i>CONSTRUCTION QUALITY ASSURANCE AND QUALITY CONTROL AT LANDFILLS</i>	489
20	Camelia Madear, Gelu Madear <i>DESIGN OF LEACHATE COLLECTION SYSTEM USING MONTE CARLO SIMULATION</i>	495
21	Corina Dufour, Larisa Ivascu, Adrian Mateescu, Anca Draghici <i>A PROPOSED INVENTORY OF SUSTAINABLE DEVELOPMENT INDICATORS FOR THE MANUFACTURING PROCESS ASSESSMENT</i>	499
22	Buia Grigore, Nimară Ciprian <i>QUALITY ASSESSMENT OF PETROȘANI URBAN LANDSCAPE</i>	505
23	Daniela Ionela Ciolea, Emilia Cornelia Dunca <i>THE UNDERGROUND SPACE, A SOLUTION FOR THE PROTECTION OF THE ENVIRONMENT</i>	509
24	Apostu Izabela Maria, Lazar Maria, Faur Florin <i>VISUAL ANALYSIS OF DEFORMATIONS FROM THE QUARRY AND INNER DUMP STEPS FROM NORTH PESTEANA MINING PERIMETER</i>	515

<b>SECTION 4.</b>		
<b>INNOVATIONAL CHALLENGES IN ELECTRICAL ENGINEERING AND ENERGETICS TECHNOLOGY</b>		
1	Niculescu Titu, Păsculescu Dragos <i>QUALITY IMPROVEMENT OF SWITCHING PARAMETERS AT SWITCHING WITH DC HYBRID BREAKER</i>	<b>519</b>
2	Pană Leon, Pasculescu Dragos, Florentiu Deliu <i>MANAGEMENT OF THE OPTIMAL OPERATING STATES OF ELECTRICAL DISTRIBUTION STATIONS</i>	<b>525</b>
3	Danut Grecea, Sorin Burian, Marius Darie, Tiberiu Csaszar, Cosmin Colda, Adriana Andris, Gabriela Pupazan, Lucian Moldovan <i>ISSUES CONCERNING THE REQUIREMENTS FOR THE ACHIEVEMENT OF A SPARK TEST APPARATUS SIMULATOR FOR LINEAR CIRCUITS</i>	<b>531</b>
4	Lucian Moldovan, Sorin Burian, Mihai Magyari, Dragos Fotau, Marcel Rad, Diana Salasan <i>CONSIDERATIONS REGARDING THE ASYMMETRIC PULSE AND ASYMMETRIC POWER TESTS OF ELECTRONIC BALLASTS FOR FLUORESCENT LUMINAIRES WITH TYPE OF PROTECTION INCREASED SAFETY "E" DESIGNED FOR USE IN EXPLOSIVE ATMOSPHERES</i>	<b>537</b>
5	Marcel Daniel Rad, Sorin Burian, Mihai Magyari, Lucian Moldovan, Dragos Fotau, Diana Salasan <i>STUDY AND EVALUATION OF REQUIREMENTS FOR BREATHING AND DRAINING DEVICES</i>	<b>543</b>
6	Dragos Fotau, Sorin Burian, Mihai Magyari, Lucian Moldovan, Marcel Daniel Rad, Diana Salasan <i>THERMAL ENDURANCE TESTS PERFORMED ON EQUIPMENT USED IN POTENTIALLY EXPLOSIVE AREAS</i>	<b>549</b>
7	Cosmin Colda, Sorin Burian, Marius Darie, Tiberiu Csaszar, Danut Grecea <i>CONSIDERATIONS ABOUT THE ENCAPSULATED EQUIPMENT TESTS</i>	<b>553</b>
8	Mihai Magyari, Sorin Burian, Lucian Moldovan, Dragos Fotau, Marcel Daniel Rad <i>INFLUENCE OF THE VOLUME AND GEOMETRICAL SHAPE OF LARGE ELECTRIC MOTOR ENCLOSURES ON THE EXPLOSION PRESSURES WHEN TESTED IN EXPLOSIVE MIXTURES</i>	<b>557</b>
9	Adriana Andriș, Constantin Sorin Burian, Marius Darie, Tiberiu Atila Csaszar, Iosif Lucian Moldovan, Cosmin Ioan Colda, Dănuț Nicolae Grecea, Gabriela Pupazan <i>ASPECTS ON SMALL COMPONENTS IGNITION TEST USING EXPLOSIVE GAS MIXTURES</i>	<b>563</b>
10	Stochitoiu Maria Daniela, Utu Ilie <i>THE LIMITS OF ELECTRICAL GRID FOR INCREASING THE QUALITY IN THREE PHASES SYSTEMS THROUGH THE POWER FLOW CONTROL</i>	<b>569</b>
11	Stochitoiu Maria Daniela, Marcu Marius Daniel <i>INNOVATIVE AND QUALITY SOLUTIONS WITH HVDC AND FACTS – FACE TO THE NEW CHALLENGES</i>	<b>573</b>
12	Mariana Dumitrescu <i>INFLUENCE OF POWER QUALITY AND EFFICIENCY FOR AN ENERGY DELIVERY SYSTEM REAL STUDY CASE APPLICATION</i>	<b>577</b>
13	Mariana Dumitrescu <i>INTELLIGENT ELECTRICAL MICRO NETWORK APPLICATION WITH DISTRIBUTED ENERGY RESOURCES</i>	<b>581</b>
14	Krasimir Marinov Ivanov, Tsviatko Kolev Varbov, Georgi Tsonev Veleve, Panayot Ivanov Yankov <i>STUDY OF THE ELECTROMAGNETIC COMPATIBILITY PARAMETERS OF LED LIGHTING SOURCES</i>	<b>587</b>
15	Dragos Pasculescu, Leon Pana, Georgeta Buica, Vlad Mihai Pasculescu, Remus Dobra <i>A QUALITY-BASED APPROACH FOR IMPROVING THE LIGHTING DESIGN PROCESS</i>	<b>593</b>
16	Marius-Daniel Marcu, Florin Gabriel Popescu, Titu Niculescu, Razvan-Ioan Slusariuc, Maria Daniela Stochitoiu <i>QUALITY MANAGEMENT ALGORITHM USED IN A PROGRAMMABLE MICROCONTROLLER AS MAXIMUM POWER POINT TRACKER</i>	<b>599</b>

17	Titu Niculescu, Florin Gabriel Popescu, Marius Marcu, Ioan Razvan Slusariuc <i>IMPROVING THE QUALITY OF MEASUREMENTS IN ELECTRICAL PROCESSES USING NI USB DATA ACQUISITION SYSTEMS</i>	<b>605</b>
18	Mircea Risteiu, Remus Dobra, Constantin Hutanu, Dragos Pasculescu, Constantin Beiu <i>VECTORIAL APPROACH IN SMART GRID DIRECTIONAL PROTECTION USING HIGH SPEED MICROCONTROLLERS</i>	<b>611</b>
19	Remus Dobra, Mircea Risteiu, Florin Samoila, Dragos Pasculescu, Georgeta Buica <i>COMPUTATIONAL BASED METHOD FOR SMART DIFFERENTIAL PROTECTION OF THE ELECTRICAL POWER NETWORKS</i>	<b>617</b>
<b>SECTION 5.</b>		
<b>DEVELOPMENTS IN SYSTEMS CONTROL, INFORMATION TECHNOLOGY AND CYBERSECURITY</b>		
1	Peyo Hristov, W. Dimitrov <i>THE BLOCKCHAIN AS A BACKBONE OF GDPR COMPLIANT FRAMEWORKS</i>	<b>623</b>
2	Gheorghica Radu- Iulian <i>ALGORITHMS FOR GRAPH ISOMORPHISM. A COMPARATIVE STUDY</i>	<b>629</b>
3	Roxana-Elena Tudoroiu, Sorin-Mihai Radu, Nicolae Tudoroiu <i>REAL TIME CONTROL STRATEGY FOR IMPROVING THE PLASMA QUALITY IN NONLINEAR REACTIVE ION ETCHERS</i>	<b>635</b>
4	Rîurean Simona Mirela, Leba Monica, Ionica Andreea <i>VLC EMBEDDED MEDICAL SYSTEM ARCHITECTURE BASED ON MEDICAL DEVICES QUALITY REQUIREMENTS</i>	<b>641</b>
5	Mirela Praisler, Stefanut Ciochina, Marian Coman <i>MACHINE LEARNING APPLICATION DETECTING POTENT ILLICIT CENTRAL NERVOUS SYSTEM STIMULANTS</i>	<b>647</b>
6	Stefanut Ciochina, Mirela Praisler, Marian Coman <i>SCANNING FOR ILLICIT PSYCHOACTIVE DRUGS BASED ON PATTERN RECOGNITION</i>	<b>653</b>
7	Cosmin Rus, Monica Leba <i>LIVE CAR TRAFFIC MONITORING WITH RASPBERRY PI HARDWARE</i>	<b>659</b>
8	Raluca Dovleac, Ahmad Sad, Andreea Ionica, Monica Leba <i>QUALITY MANAGEMENT AND WEB 2.0 TOOLS EMBEDDED IN THE AGILE APPROACH FOR EDUCATION</i>	<b>665</b>
9	Luminița Giurgiu, Dănuț Moșteanu <i>QUALITY IN WEB DESIGN – TRENDS AND RESPONSIVENESS TECHNIQUES</i>	<b>671</b>
10	Marius Risteiu, Monica Leba, Andrei Arad <i>EXOSKELETON FOR IMPROVING QUALITY OF LIFE FOR LOW MOBILITY PERSONS</i>	<b>677</b>
11	Patrascoiu Nicolae, Cosmin Rus <i>INCREASE THE QUALITY OF TEMPERATURE MEASUREMENTS USING VIRTUAL INSTRUMENTATION</i>	<b>683</b>
12	Rus Cosmin, Patrascoiu Nicolae <i>A MOBILE SYSTEM BASED ON LIDAR TECHNOLOGY USED FOR DATA ACQUISITION IN TRAFFIC MANAGEMENT</i>	<b>689</b>
13	Peyo Hristov, W. Dimitrov <i>THE BLOCKCHAIN AS A BACKBONE OF GDPR COMPLIANT FRAMEWORKS</i>	<b>695</b>
<b>SECTION 6.</b>		
<b>INDUSTRIAL AND MECHANICAL ENGINEERING AND TRANSPORTATION</b>		
1	Teodora Hristova <i>METHODOLOGY FOR DETERMINING THE REPLACEMENT PERIOD FOR LIFTER BARS</i>	<b>701</b>
2	Marin Silviu Nan, Danut Grecea, Stela Dinescu, Andreea Ungur, Alin Sultan <i>INCREASING QUALITY THROUGH THE STUDY OF THE USE OF EXTRACTION COMPLEXES USING MODERN METHODS OF MATHEMATICAL STATISTICS</i>	<b>707</b>
3	Zoltán Virág, Viktor Fülöp, József Molnár <i>DEVELOPMENT OF A CUTTING AND HAULING DEVICE FOR LIMESTONE DIMENSION STONE MINES</i>	<b>713</b>
4	Rusu Robert, Alexandru Tudor – George, Monica Manole <i>A TWO-STAGE MACRO BASED APPROACH FOR DEVELOPING AIRCRAFT ENGINE COMPONENTS CONCESSIONS BASED ON SURFACE MORPHING TECHNOLOGIES</i>	<b>717</b>

5	Sorin Mihai Radu, Florin Dumitru Popescu, Andrei Andras, Ildiko Kertesz Brinas, Ovidiu Bogdan Tomus <i>INCREASING THE QUALITY OF THE WELL DRILLING PROCESS BY FINITE ELEMENT ANALYSIS OF THE DRILLING FLUID FLOW PARAMETERS</i>	723
6	Sorin Mihai Radu, Florin Dumitru Popescu, Andrei Andras, Ildiko Kertesz Brinas, Ovidiu Bogdan Tomus <i>SIMULATION AND MODELLING OF THE FORCES ACTING ON THE ROTOR SHAFT OF BWES, IN ORDER TO IMPROVE THE QUALITY OF THE CUTTING PROCESS</i>	729
7	Ana Gavriluta <i>STUDY ON IMPROVEMENT OF A MANUFACTURING SYSTEM USING LEAN MANUFACTURING</i>	735
8	Ana Gavriluta <i>DESIGN OF A LEARNING PLATFORM FOR 5S METHOD FOR USING TO IMPROVE A MANUFACTURING SYSTEM</i>	741
9	Daniel Șerban, Constantin Gheorghe Opran <i>ANALYSIS OF MICRO-PROFILE MACHINING OF THE NON-PLANAR SURFACES OF INJECTION MOLDS FOR POLYMERIC COMPOSITES</i>	745
10	Pavla Hlavatá, Jiří Maxa <i>FLOW ANALYSIS OF THE PRESSURE DISTRIBUTION IN THE EXPERIMENTAL CHAMBER OF THE DIFFERENTIAL PUMPING</i>	749
11	Iosif Dumitrescu, Razvan-Bogdan Itu <i>FRANGIBLE COUPLING A SAFETY ELEMENT IN AIRPORTS' TRAFFIC</i>	755
12	Mihaela Dana Racz, Dan Codrut Petrilean <i>THE INFLUENCE OF HUMIDITY ON AIR TEMPERATURE IN UNDERGROUND MINES AS A FACTOR OF AIR QUALITY ASSESSMENT</i>	761
13	Adriana Zamora, Sorina Stanila <i>THE ASSESSMENT OF FACTORS WHICH INFLUENCE THE ENERGETIC EFFICIENCY OF HELICAL SCREW COMPRESSORS FOUND IN COAL MINES</i>	767
14	Olimpiu Stoicuta, Marin Nan, Danut Grecea, Catalin Plotogea <i>MODELING AND SIMULATION OF THE STERILE ROCKS EXCAVATION PROCESS USING BUCKET WHEEL EXCAVATORS</i>	773
15	Vlad Alexandru Florea <i>RESEARCHES ON WEAR AND RELIABILITY OF SOME SUBASSEMBLIES AND SPARE PARTS OF TECHNOLOGICAL EQUIPMENTS</i>	779
16	Praporgescu Gabriel <i>THE USE OF QUALITY FUNCTION DEPLOYMENT METHOD IN THE TRANSPORT ACTIVITY</i>	785
17	Ilioni Cristian <i>QUALITY OF EQUIPMENT USED IN THE MINING INDUSTRY</i>	791
18	Dosa Ioan, Ovidiu Bogdan Tomus <i>POWER DEMAND OF THE TK-R 16/8 TURBOCOMPRESSOR FUNCTION OF INLET CONDITIONS</i>	795
19	Vatavu Sorin <i>PLUNGER HYDRAULIC MACHINES. TYPOLOGY, CALCULATION PRINCIPLES AND APPLICATIONS IN MINING</i>	799
<b>SECTION 8.</b>		
<b>RECENT TRENDS IN BUSINESS, ECONOMICS, LAW AND PUBLIC ADMINISTRATION</b>		
1	Janusz Wielki, Artem Stopochkin, Inessa Sytnik <i>INVESTMENT PORTFOLIO MANAGEMENT BASED ON THE STUDY OF THE COMPETITIVENESS OF JOINT-STOCK COMPANIES</i>	805
2	Nur Feriyanto, Sebastian Kot, Dyah Sugandini, Muafi <i>THE DEVELOPMENT OF COMMUNITY BASED TOURISM: FROM ATTRACTIVENESS TO LOYALTY</i>	811
3	Muafi, Janusz Grabara, Sudiyarto, Yuni Siswanti <i>BUSINESS STRATEGY, ORGANIZATIONAL STRUCTURE, WORK PROCESSES: ARE THE ALIGNMENT?</i>	817

4	Răvaș Bogdan <i>SOME CONSIDERATIONS ON MANAGEMENT INTERNAL CONTROL OF STOCKS IN THE FIELD OF CONSTRUCTION SOCIETIES</i>	823
5	Niță Dorina <i>THE GENDER GAP IN THE LABOUR MARKET</i>	829
6	Elena Iuliana Ion, Mariana Man <i>ECONOMIC VALUE ADDED RELEVANCE FOR STAKEHOLDERS REGARDING THE QUALITY OF PERFORMANCE ANALYSIS OF ROMANIAN METALLURGICAL COMPANIES</i>	835
7	Rus Cosmin, Rakos Ileana Sorina <i>BITCOIN - THE ECONOMIC UNIT OF HUMANITY?</i>	841
8	Isac Claudia <i>MANAGEMENT OF SUCCESSION IN FAMILY BUSINESSES</i>	847
9	Ana Petrina Păun, Mirela Monea, Codruța Dura <i>SOME PRACTICAL TOOLS TO MITIGATE OCCUPATIONAL SAFETY AND HEALTH RISKS WITHIN THE INDUSTRIAL ENVIRONMENT</i>	853
10	Codruța Dura, Imola Drigă, Ana Petrina Păun <i>OHS DISCLOSURE IN ROMANIA IN THE FRAMEWORK OF CSR REPORTING</i>	859
11	Michal Pohludka, Hana Štverková, Aleš Panna <i>PROPER HR AUDIT AND DUE DILIGENCE PROCESS: KEY FACTORS IN A SUCCESSFUL ACQUISITION</i>	865
12	Gabriela Corina Slusariuc <i>THE QUALITY OF LENDING THE ECONOMY</i>	871
13	Tatiana Antipova <i>DIGITAL PUBLIC SECTOR AUDITING: A LOOK INTO THE FUTURE</i>	877
14	Olga Bucovetchi, Radu D. Stanciu, Dorel Badea <i>IS OUTSOURCING THE BEST SOLUTION IN INCREASING ORGANISATIONAL PERFORMANCE?</i>	883
15	Oana Dobre-Baron, Alina Nițescu <i>TRADE MARKETING – AN INNOVATIVE CONCEPT IN LOGISTIC COOPERATION BETWEEN MANUFACTURERS AND TRADERS</i>	887
16	Alina Nițescu, Oana Dobre-Baron <i>ANALYSIS OF THE ROMANIAN AGRICULTURAL SECTOR IN EUROPEAN CONTEXT</i>	893
17	Ciurea Maria <i>THE PUBLIC-PRIVATE PARTNERSHIP IN ROMANIA -THEORETICAL APPROACHES</i>	899
18	Ciurea Maria <i>CONSIDERATIONS ON THE NEED TO IMPLEMENT INTERNATIONAL ACCOUNTING STANDARDS FOR THE PUBLIC SECTOR IN ROMANIA</i>	905
19	Ivan Zaytsev, Alexakhin A.V., Sala D.P. <i>THE PLANNING OF BUSINESS PROCESSES IN UNDEFINED CONDITION OF OLIGOPOLISTIC MARKET</i>	911
20	Alexakhin A.V., Rozhkov I.M., Zaytsev I.M., Yu.Yu. Kostyukhin <i>THE PLANNING AND MANAGEMENT OF THE OWNER'S EARNING WITH USING SIMULATION MODELING</i>	917
21	Răscolean Ilie, Rakos Ileana Sorina <i>THE SUBSTANTIATION OF CASH FLOWS WITHIN A BUSINESS PLAN</i>	921
22	Marzena Szewczuk-Stępień, Brygida Klemens <i>ESSENCE AND ROLE OF CO-OPERATION IN REGIONAL DEVELOPMENT. RIS3 CASE STUDY</i>	927
23	Mircea Baron, Oana Dobre-Baron <i>MANAGERIAL CONCERNS FOR THE EXIT OF 1929-1933 ECONOMIC CRISIS IN THE JIU VALLEY COAL MINING INDUSTRY</i>	933
24	Janusz Wielki, Przemysław Koziół <i>OPTIMIZATION OF BUSINESS PROCESSES WITH THE USE OF MICROLOCATION TOOLS BASED ON THE INDUSTRY 4.0 CONCEPT</i>	939
25	Alexandru Constantin Petrache <i>LOGISTICS PARKS – FROM THEORY TO PRACTICE IN ROMANIA</i>	945

26	Mădălina Dumitrița Maticiuc <i>CLUSTERS – VALUE ADDED CREATORS FOR SMES</i>	949
27	Tatiana Dănescu, Maria Alexandra Botoș <i>ANALYSIS OF COMPANIES' BEHAVIOR IN SMOOTHING CONFLICTS OF INTEREST</i>	953
28	Alina Natalia Pop, Gabriel Rus <i>ANALYSIS OF MANAGERS BEHAVIOR IN INDUSTRIAL COMPANIES IN THE NORTH WEST REGION</i>	959
29	Guta Anca Jarmila <i>UTILIZATION OF "VALUE ANALYSIS" IN DETERMINATION OF COMPETITIVENESS LEVEL WITH IN S.C. EUROSPORT DHS SA</i>	965
30	Waseem-UI-Hameed, Muhammad Imran, Beata Ślusarczyk, Adnan ul Haque <i>THE MODERATING ROLE OF MALAYSIAN GOVERNMENT IN MICROCREDIT ORGANIZATION AND QUALITY OF WOMEN SELF-SUSTAINABILITY</i>	971
31	Mohammad Jaradat, Sergiu-Dan Iurian <i>ADAPTING LEADERSHIP METHODS TO GLOBAL CHALLENGES: INTERACTIVE LEADERSHIP</i>	977
32	Sergiu-Dan Iurian, Mohammad Jaradat <i>THE IMPORTANCE OF CULTURAL MARKETING IN EVALUATING CREATIVE PERSONNEL</i>	981
33	Monica Aureliana Petcu, Iulia Maria David-Sobolevski, Irina Daniela Cișmașu <i>DIMENSIONS AND INDICATORS OF QUALITY MANAGEMENT ASSESSMENT IN THE CONTEXT OF SUSTAINABLE DEVELOPMENT</i>	987
34	Vasile Robu, Irina Daniela Cișmașu, Alma Maria Petcu <i>THE ASSESSMENT OF THE QUALITY OF LEADERSHIP AS A RESOURCE FOR SUSTAINABLE DEVELOPMENT</i>	993
35	Cristea Loredana Andreea <i>INCREASING THE QUALITY OF THE TAXES AND FEES IMPACT ASSESSMENT ON THE ROMANIAN ECONOMY</i>	999
36	Ungureanu Adelin, Ravaș Oana <i>THE INSTITUTIONAL RELATIONS BETWEEN STATE POWERS</i>	1005
37	Fetiniuc Valentina, Luchian Ivan, Tvircun Alexandra <i>MODERN APPROACHES OF BANKING GLOBALIZATION</i>	1011
<b>SECTION 9.</b>		
<b>CONTEMPORARY APPROACHES IN QUALITY ASSURANCE, MANAGEMENT AND MARKETING</b>		
1	Pleșa Roxana <i>PERFORMING UNIVERSITY MANAGEMENT - A DETERMINANT FACTOR IN QUALITY ASSURANCE IN EDUCATION</i>	1017
2	Ghicajanu Mihaela <i>TECHNIQUES TO CONTINUALLY IMPROVE BUSINESS QUALITY AND PERFORMANCE (I)</i>	1023
3	Ghicajanu Mihaela <i>TECHNIQUES TO CONTINUALLY IMPROVE BUSINESS QUALITY AND PERFORMANCE (II)</i>	1027
4	Székely Szilárd, Adriana Benedek, Lucian-Ionel Cioca, <i>QUALITY SUPPLIER RESPONSE TO INDUSTRIAL PROCUREMENT BEHAVIOR ON THE SOUTH EAST EUROPEAN METAL DISTRIBUTION MARKET</i>	1031
5	Lupu-Dima Lucian, Eduard Edelhauser, Emilia Corina Corbu, Amalia Furdui <i>INNOVATIVE METHOD OF INCREASING THE QUALITY OF MANAGEMENT IN ADMINISTRATION USING THE PRINCIPLES OF SHARING ECONOMY</i>	1037
6	Amalia Furdui, Eduard Edelhauser, Elena-Izabela Popa <i>INNOVATION MANAGEMENT CORRELATED WITH THE MODELS OF DEVELOPMENT OF TECHNOLOGICAL ENTREPRENEURSHIP</i>	1043
7	Roland Iosif Moraru, Tomasz Dub, Mariusz Sroka <i>GROUP DEVELOPMENT PROCESS IN MANAGEMENT OF WORK TEAMS</i>	1049
8	Emilia Corina Corbu, Eduard Edelhauser, Lupu-Dima Lucian <i>ANALYTIC DASHBOARD, A SOLUTION FOR INCREASING EFFICIENCY IN MANAGEMENT OF THE PUBLIC ADMINISTRATION</i>	1055



9	Eugenia Jornea, Eduard Edelhauser, Amalia Furdui <i>ASPECTS CONCERNING THE QUALITY OF MANAGEMENT PROJECTS DESIGNED FOR RESTRUCTURING THE ECONOMY</i>	1061
10	Aleksandra Ptak <i>CORPORATE SOCIAL RESPONSIBILITY IN POLISH ENTREPRISES</i>	1067
11	Agnieszka Noga <i>INNOVATION OF THE PRODUCT AS A SIGNIFICANT FACTOR IN THE CONCEPT OF THE DEVELOPMENT OF A TOY INDUSTRY ENTERPRISE</i>	1073
12	Tomasz Lis <i>INFORMATION AND CUSTOMER PURCHASE DECISIONS ON DYNAMIC MARKETS</i>	1079
13	Elzbieta Karas <i>THE ONLINE CONSUMERS' RECOMMENDATIONS</i>	1085
14	Muafi, Joanna Tabor, Benny Wendry, Jun Surjanti, Rizqi Adhyka Kusumawati <i>BUILDING ORGANIZATIONAL INNOVATION THROUGH STRATEGIC ORIENTATION: A LESSON FROM CEMENT INDUSTRY IN INDONESIA</i>	1091
15	Elena-Izabela Popa, Eduard Edelhauser, Eugenia Jornea <i>ASPECTS OF ORGANISATIONAL CULTURE AND CHANGE MANAGEMENT</i>	1097
16	Rus Ioan <i>INTEGRATION OF HUMAN RESOURCES STRATEGY IN THE GENERAL STRATEGY OF AN ENTERPRISE</i>	1103
17	Criveanu Maria Magdalena <i>DISCREPANCIES IDENTIFIED AT AN ORGANIZATIONAL LEVEL BETWEEN MANAGERS AND EMPLOYEES</i>	1109
18	Irimie Sabina, Adrian Pal <i>ADVANCES IN OCCUPATIONAL ERGONOMICS AND RISK MANAGEMENT</i>	1113
<b>SECTION 11.</b>		
<b>EDUCATION RESEARCH, SUSTAINABLE DEVELOPMENT AND INTERDISCIPLINARY STUDIES</b>		
1	Mansour Radwan <i>MINORITY IN THE MIDDLE EAST: THE MONOTHEISTS "DRUZE" IN THE MIDDLE EAST, CHANGES AND COMPETES</i>	1119
2	Khatib Mhana <i>DIGITAL GAME – GAME OR DANGER?</i>	1123
3	Sarsour Raed, Sarsour Alaa <i>CHANGE MANAGEMENT PROCESS AND ITS CHARACTERISTICS IN SCHOOLS</i>	1129
4	Sarsour Alaa, Sarsour Raed <i>MANAGING THE IMPLEMENTATION OF INFORMATION TECHNOLOGY (IT) AND ITS INFLUENCE IN SCHOOL</i>	1133
5	Faraj Faraj <i>THE CONTRIBUTION OF DRUZE WOMEN TO THE DEVELOPMENT OF DRUZE SOCIETY</i>	1137
6	Jeanina Ciurea, Suzana Demyen <i>A COMPARATIVE STUDY REGARDING THE INNOVATION ACTIVITY OF VARIOUS ENTITIES, IN A GLOBAL PERSPECTIVE</i>	1141
7	Ilie Mihai Taucean, Larisa Ivascu, Serban Miclea, Mircea Liviu Negrut <i>SYNERGIES BETWEEN LEAN AND SUSTAINABILITY: A LITERATURE REVIEW OF CONCEPTS AND TOOLS</i>	1147
8	Stelescu Ioan <i>STUDY REGARDING OPTIMUM FUNCTIONALITY OF ANALYZERS (MOTOR AND OPTIC) INCREASING THE PRECISION AND EFFICIENCY IN BALL TRANSMISSION</i>	1153
9	Stelescu Ioan <i>STRENGTH AND DISTANCE IN RELATION WITH INTENSITY OF THROWING, RUNNING AND JUMPING IN YOUTH FOOTBALL</i>	1159
10	Constantin Dan Buioca <i>PHYSICS LABS FOR ENGINEERING STUDENTS: A CASE STUDY BASED ON “LEARNING BY DOING” PRINCIPLES</i>	1163
11	Constantin Dan Buioca <i>OPTICAL STUDY OF SAHARAN DUST TRANSPORTED IN JIU VALEY IN 2018</i>	1167

12	Janusz Grabara <i>SUSTAINABLE DEVELOPMENT - NEVER FULFILLED DREAM</i>	<b>1171</b>
13	Boatca Maria - Elena, Drăghici Anca <i>ROLE OF ERGONOMICS IN SUSTAINABLE DEVELOPMENT</i>	<b>1177</b>
14	Călina Ana Buțiu <i>"PRO-INTEGRA" PROJECT'S COMPARATIVE SURVEY OF MAIN STAKEHOLDERS' OPINIONS ON THE EDUCATIONAL OFFER OF "1 DECEMBRIE 1918" UNIVERSITY OF ALBA IULIA</i>	<b>1183</b>
15	Dariusz Rajchel <i>FINANCING THE DEVELOPMENT OF THE CITY OF OPOLE BASED ON ITS BUDGET</i>	<b>1187</b>
16	Anna Rajchel <i>A GRADUATE OF A SECONDARY SCHOOL ON THE LABOUR MARKET. CHANCES AND THREATS</i>	<b>1193</b>
17	Cremene Cosmin Sergiu <i>THE ANALYSIS OF THE CONTENT OF NEWSPAPERS: „CRONICA VĂII JIULUI”, „GAZETA DE DIMINEAȚĂ” AND „ZIARUL VĂII JIULUI”</i>	<b>1199</b>
18	Cremene Cosmin Sergiu <i>RESIDENTS' PERCEPTION OF THE STUDIED COMMUNITIES THROUGH A DIRECT SURVEY</i>	<b>1205</b>
19	Nabila Kheir Faddul, Nicolae Aurelian Bibu, Doina Dănăiață <i>THE ORGANIZATIONAL CULTURE IN JUNIOR HIGH SCHOOLS IN THE DRUZE SECTOR</i>	<b>1211</b>
20	Mihaela- Camelia Schmidt <i>POPULATION AGEING, A CONSEQUENCE OF TRANSITION</i>	<b>1217</b>
21	Sima Ioan <i>A COMBINATORIAL GRAY WOLF OPTIMIZATION ALGORITHM FOR FINDING 2D PROTEIN CONFORMATION</i>	<b>1221</b>
22	Esther Andras <i>USING FILM TO INTERPRET LITERATURE: CHARLES DICKENS' "A CHRISTMAS CAROL"</i>	<b>1227</b>
23	Laura Marica, Cristian Siminic Ilioni <i>SPORT - AN INEXPENSIVE WAY OF TREATMENT FOR POOR PEOPLE</i>	<b>1231</b>

## The possibility of safety improvement through exogenous fire prediction in mine workings and transport tunnels

Guram Abashidze<sup>a</sup>, Nicolae Ilias<sup>b\*</sup>, Roland Moraru<sup>b</sup>, Davit Tsverava<sup>a</sup>

<sup>a</sup>*G. Tsulukidze Mining Institute, 0177, Tbilisi, Mindeli Street, 7, Georgia*

<sup>b</sup>*University of Petrosani, University Str. no. 20, Petrosani, Romania*

---

\*Kindly presented by Prof. O. Lanchava – Project Investigator № 216968 “Prevention methods development against aerosol terrorisms for ventilation of Tbilisi subway”, financed by SRNSF.

---

### Abstract

There are two positions describing fire growth in a building - the differential and integral level of the process description. The first approach is based on the study of the equations of continuum mechanics. The system of these equations describes the change in time of density, pressure, temperature and composition of the gaseous medium at individual points of the structure's volume. However, this system is cumbersome and its solution encounters great difficulties. Taken into account this circumstance, as well as the fact that there is no need for such a detailed study of the process to perform the calculations, the concept describing fire growth at a differential level should be considered unacceptable for engineering practice. The integral level of the description of fire growth foresees determination of the state parameters by the averaged volume structure and allows to reveal the general regularities of the process of fire growth. Complex physical processes are considered by integral characteristics obtained experimentally. In the proposed work, based on the study of physical processes occurring during underground exogenous fires, and based on laws on the conservation of mass and energy, the system of differential equations is proposed. It describes fire growth in a specific section of the mine working/tunnel, called as a zone of fire growth; The possibility of determining the temperature beyond the zone of fire growth, through the chain of excavations/tunnels is shown; The necessity of physical modeling of the process of fire growth is justified, the requirements providing similarity of the process in nature and on the model are determined; The formulas for calculating the parameters behind the zone of fire growth are recommended.

**Keywords:** a zone of exogenous fire growth; constant velocity of fire center movement; time of fire growth; polysulfide sealant and anti-corrosion coatings such as fire load.

---

### 1. Introduction

The problem of protection underground structures (capital and preparatory production of mines and deposits, transport tunnels) from exogenous fire, arose at the end of the last century. The statistics of underground fires forced specialists to state a number of scientific problems of an experimental and theoretical nature [Kumar, 1992; Ingason, 1985; Haack, 1992; Mikkola, et al, 1987]. In recent years, as new materials effective in terms of operational characteristics have appeared and a computer technology has progressed, the work in this domain has been developed and a number of recommendations have been offered allowing to reduce the risk of underground fires [Ilias et al, 2017; Lanchava et al, 2017; Moraru et al, 2012, 2017]. Reduction of the risk of fires is also resulted by the prediction of the development of this process and the development of prevention measures.

It has been shown that it is possible to describe underground exogenous fire using a system of differential equations (for the fire growth zone) and some calculated empirical formulas (for beyond the fire growth zone, along the length / chain of the structure) [Abashidze et al, 1986, 2006].

Through the development of this mathematical apparatus, the following works were used [Koshmarov, 1981; Davidkin, 1996]. Below, there is a system of differential equations describing the process in the fire growth zone.

---

\* Corresponding author. Tel.: +40737992546  
E-mail address: iliasnic@yahoo.com

$$P_{av} = \rho_{av} R_{av} T_{av} \quad (1)$$

$$V_{fg} d\rho_{av}/d\tau = G_a + \Psi F_{com} - G_g \quad (2)$$

$$\rho_{av} V_{fg} d\bar{C}_{O_2}/d\tau = G_a(\bar{C}_{O_2}^a - \bar{C}_{O_2}) + G_g \bar{C}_{O_2}(1 - n_1) - \Psi F_{com}(\eta L_{O_2} + \bar{C}_{O_2}) \quad (3)$$

$$\rho_{av} V_{fg} d\bar{C}_{CO_2(CO)}/d\tau = \Psi F_{com}(L_{CO_2(CO)} - \bar{C}_{CO_2(CO)}) - G_g \bar{C}_{CO_2(CO)}(n_2 - 1) - G_a \bar{C}_{CO_2(CO)} \quad (4)$$

$$\rho_{av} V_{fg} d\bar{C}_{N_2}/d\tau = G_a(\bar{C}_{N_2}^a - \bar{C}_{N_2}) - \Psi F_{fg} \bar{C}_{N_2} \quad (5)$$

$$\frac{V_{fg}}{K-1} dP_{av}/d\tau = Q_{av} \Psi F_{com} \eta + C_p^a G_a T_a + \Psi F_{fg} \mathcal{Y} - Q_{lin} - m c_{(p)av} T_{av} G_g \quad (6)$$

Entry conditions: at  $\tau = 0$   $\rho_{av} = \rho_{av}^0$ ;  $T_{av} = T_{av}^0$ ;  $\bar{C}_{O_2} = \bar{C}_{O_2}^0$ ;  $\bar{C}_{CO_2(CO)} = \bar{C}_{CO_2(CO)}^0$ ;  $\bar{C}_{N_2} = \bar{C}_{N_2}^0$

The notations accepted in the equations are:  $\Psi$  – burnout rate,  $\text{kg} \cdot \text{m}^{-2} \cdot \text{s}^{-1}$ ;  $\eta$  – completeness of combustion;  $L_{O_2}$  – the mass of oxygen required to combust a unit of material mass,  $\text{kg} \cdot \text{kg}^{-1}$ ;  $L_{CO_2(CO)}$  – the mass of products formed at combustion of a unit of material mass  $\text{kg} \cdot \text{kg}^{-1}$ ;  $\mathcal{Y}$  – enthalpy of a substance formed during the decomposition of the material,  $\text{joule} \cdot \text{kg}^{-1}$ . The others:  $P_{av}$ ,  $\rho_{av}$ ,  $R_{av}$ ,  $T_a$  – accordingly average-volumetric pressure, Pa, density,  $\text{kg} \cdot \text{m}^{-3}$ , gas constant,  $\text{joule} \cdot \text{kg}^{-1} \cdot \text{K}^{-1}$ , air temperature, K;  $V_{fg}$  – volume of fire growth,  $\text{m}^3$ ;  $F_{com}$  – area of combustion,  $\text{m}^2$ ;  $\bar{C}_{O_2}$ ,  $\bar{C}_{CO_2(CO)}$ ,  $\bar{C}_{N_2}$  – accordingly concentration of oxygen, products of combustion and nitrogen;  $\tau$  – time, sec;  $G_a$  and  $G_g$  – accordingly quantity (consumption) of air and gas,  $\text{kg} \cdot \text{s}^{-1}$ ;  $K$  – adiabatic index;  $C_p$  – heat capacity of gas,  $\text{joule} \cdot \text{kg}^{-1} \cdot \text{K}^{-1}$ ;  $Q_{lin}$  – heat flow in the lining of the structure, W;  $n_1 = \bar{C}_{O_2}^g / \bar{C}_{O_2} (\leq 1)$ ;  $n_2 = \bar{C}_{CO_2(CO)}^g / \bar{C}_{CO_2(CO)} (\geq 1)$ ;  $m = C_p T_g / (C_p)_{av} T_{av} (\geq 1)$ . The index “a” (lower or upper) concerns the air, entering the construction.

The length of the zone of fire growth is determined by the formula:

$$L_{fg} = 2C_{fg}\tau_{fg}/3 \quad (7)$$

where  $C_{fg}$  – constant velocity of fire growth,  $\tau_{fg}$  – time of fire growth.

Thus, in order to describe the fire growth in its origin zone and beyond this zone, it is required to determine experimentally:  $\eta$ ,  $L_{O_2}$ ,  $L_{CO_2(CO)}$ ,  $\mathcal{Y}$ ,  $\Psi$ , the dependences on heat and mass transfer, constant velocity and fire growth time.

## 2. Methodology and research materials

Due to the fact that laboratory tests do not provide reliable data on fire growth in the mine working / tunnels, many experts have recognized the need to conduct research on field facilities.

To select the object to carry out a full-scale testing, scientists were guided by the fact that the results obtained in the development of a certain cross-sectional area are easily transferable to another cross-sectional area. The situation is more complicated with carrying out full-scale experiments in tunnels because of their large cross-sectional area. In addition, a mine can be considered as a physical model of the tunnel and thus, under adherence of the similarity conditions to obtain the data on fire growth in tunnels. The structure selected to carry out the full-scale experiments was the 130-meter-long mine with a trapezoid cross section of  $2.8 \text{ m}^2$  abandoned by a geological–searching expedition. The mine did not have an inclined part, it was fenced on both sides by iron doors. The ventilation device injecting air into the mine, was equipped with a slide device, allowing smoothly change the velocity of the ventilation flow from  $0.5$  to  $7 \text{ m} \cdot \text{s}^{-1}$ . At the mouths, the mine had compartments for measuring equipment (Fig). The essential conditions to carry out the tests were adopted: give the testing materials the necessary humidity content, the air - necessary humidity, creation of a seat of fire of calculated capacity. Humidity content of materials was determined by Humidity meter FFM 100 and Humidity & Temperature meter & Wet Bull Temperature Dew point Temperature FHT 100. Air humidity (and other parameters of air condition, see below) was determined by Enviromux-5D\*.

For arson of structures and materials, the fires made of  $80 \text{ kg}$  of firewood and poured with  $3$  liters of kerosene were used. The given rate of the ventilating flow was monitored by the above-mentioned Enviromux-5D.

While using the mine as a model of the tunnel, its sides and roof were fixed with sheets of non-combustible material. For temperature measurements, mainly, chromel-aluminum thermocouples with recording equipment were used.

The wires of thermocouples were placed in ceramic tubes and were pulled along ditches in the soil at the depth of  $0.3 \text{ m}$ . Thermocouples were installed in  $13$  sections of the mine, as shown in Fig. The distances between sections for  $40 \text{ m}$  of the mine were  $5 \text{ m}$ . In the remaining section -  $15 \text{ m}$ .

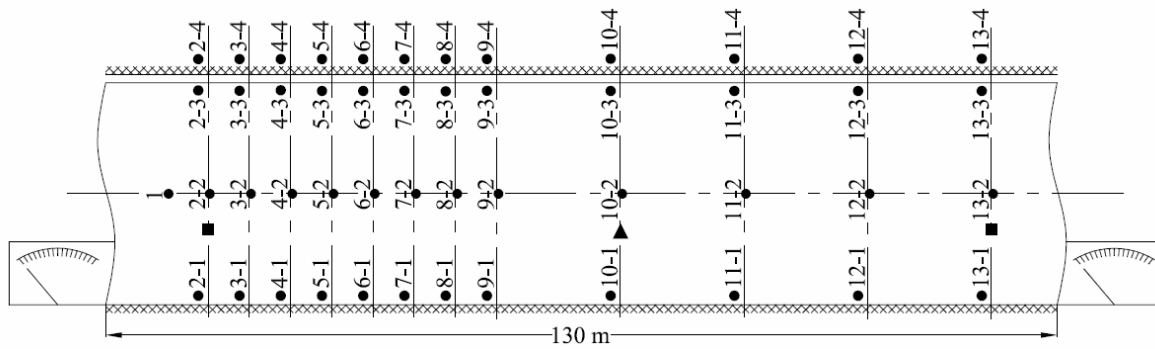


Fig. The layout scheme of thermocouples and aerometer tubes, location of air sampling.

● - thermocouples; ▲ - aerometer tubes; ■ - location of air sampling.

The rock temperatures were also measured by thermocouples at the depth of 0.5 m of the wall of the tunnel model. Enviromux-5D was used to fix the temperature at the end of the mine, as well as to the seat of fire, with fresh air jets.

The length of the combustion zone and the constant velocity of the movement of fire in the mine were determined from the dynamics of fire growth. For this purpose, the graphs of the temperature change of fire gases over the length of the mine in time were designed. The length of the combustion zone was taken where the maximum temperature of fire gases was fixed after certain time. The term "time of fire growth" means the time during of which the temperature increases up to the maximum value in the seat of fire. Enviromux-5D was used to measure the concentration of substances containing in fire gases at the end of the mine. The velocity of movement of fire gases was determined by the high-speed (dynamic) head, for the measurement of which Pitot tubes were used in combination with a micro-manometer. The density of fire gases, taking into account their temperature, was calculated by the formula  $\rho_g = 0.455P_a / (273 + t_a)$ . The consumption of materials on the model was determined taken into account that it had to be  $n^2$  times less than the material consumption in kind ( $n$  is the ratio of the mine and model dimensions). The similar moments of time were calculated from the condition  $\tau^{mo} = \tau^{nat} / n$ , where the indexes "mo" and "nat" refer to the model and nature.

As a value of the velocity of the ventilation flow, on the basis of the condition of aerodynamic similarity,  $0.8-1.2 \text{ m} \cdot \text{s}^{-1}$  was used. As a fire-retardant agent for wood, a compound made of liquid glass, fluorsilicate sodium, nepheline fire-retardant, silicomanganese slag, aluminum silicate filler (clinoptilolite) was used. Epoxy-rocked coal mastic was consisted of a mixture of epoxy resins, rocked coal resin and hardener-polyethylenepolyamine. The fireproof paint corrosion-resistant insulation was a polymer composition with kieselguhr content. The modified polysulphide sealant was consisted of factory-made polysulphide with the addition of micro-powder obtained by grinding of bentonitic clay of alkaline composition on a planetary mill.

The sealant met the exploitation requirements for insulating materials formulated in [Lanchava et al, 2017].

It is impossible to state all performed work in the context of one article. Here, only some basic outcomes are presented obtained through full-scale experiments.

### 3. Results and discussion

Totally, two experiments were carried out in the mine and on a model of the tunnel. In the mine, the support was installed from non-fireproof and fireproof wood (Experiments 1, 2). On the model, the wall was covered with epoxy-rocked coal mastic and modified sealant (Experiment 3) and fireproof pain hydro-insulation in combination with the above-mentioned sealant (Experiment 4).

**Experiment 1.** The mine was fixed with a solid wooden support between the 2 and 11 sections (Fig). Frames with the sides and roof tightened with boards 2 cm thick, racks and tops 13-17 cm in diameter were used. The distances between the frames are 1 m. Stacks of dry wood with dimensions  $1.2 \times 1.2 \times 0.7 \text{ m}$  (weight 360 kg), covered with 2 liters of kerosene and located 1 m apart were the source of firing. The picture of fire growth is as follows: after the origin of fire, the fire spread only along the ventilation flow. The fire first appeared from the seat of fire on the wall tightening in 9 minutes after firing of the source. After 20 minutes, the fire broke through to the roof. In the beginning, the flame was directed towards the ventilation flow, but later it was bound against the air flow and the support ignited behind the seat of fire. After 24 minutes, the fire spread to approximately  $12 \text{ m}^2$  of the mine. Burning fires appeared occurred from the supports dropped on the ground. Throughout the perimeter, the mine ignited after 38 minutes. After 43 minutes, the flame spread through the entire fixed section of the mine and the average temperature reached 1300 K.

The time regime of temperature can be divided into 4 stages: an increase to a maximum value (23 min), a constant maximum temperature (20 min), a temperature drop to the initial value (17 min), a normal temperature regime.

**Experiment 2.** In this case, the nature of fire growth remains the same as in Experiment 1. But a slow process of fire growth is observed. Fire appeared on the wall gripping in 15 minutes after the fire was set. The fire broke to the roof in about 45 minutes. The spread against the ventilation flow is insignificant. Throughout the perimeter, the mine did not ignite. The flame did not spread to the entire fixed area. The average volume temperature reached 640 K.

**Experiment 3.** A vigorous fire growth after its beginning was observed, and not only along the ventilation flow, but also against it. The fire first appeared on the walls near the seat of fire in 5 minutes after the fire was set.

In 16 minutes, the fire spread through approximately 25 m<sup>2</sup> of the model and melted drops of anticorrosive coating and sealant appeared. Throughout the perimeter of the model, the fire occurred after 25 minutes. Fire growth was ended by 29 minutes. The average volume temperature reached 940 K.

**Experiment 4.** The fire began with difficulty. Within the total experiment, the propagation of fire against the ventilation flow was not observed. There was no intensive dropping from the heating of the coating. The flame covered a surface of the model area of 16 m<sup>2</sup> in about 32 minutes. The fixed average volume temperature is 465 K.

Temperature of fire gases and wall/lining. The measurement results of the maximum and average volume temperatures under different values of the ventilation flow ( $v_f$ ) are shown in Table 1.

Table 1.

$C_{vf},$ $m.s^{-1}$	$T_{max}, K$	$T_{av}, K$	$T_{max}, K$	$T_{av}, K$	$T_{max}, K$	$T_{av}, K$	$T_{max}, K$	$T_{av}, K$
	Experiment 1		Experiment 2		Experiment 3		Experiment 4	
0.5	1023	911	498	408	995	912	492	446
1.0	1259	1172	650	563	1010	916	506	461
1.5	1395	1300	710	640	1015	935	521	472
3.0	1573	1498	835	753	1075	1000	567	516

The empirical formulas correspond to the presented data (their processing was carried out by the method of the least squares):

$$T_{av} = C_{vf}/(a + b)C_{vf} \quad (8) - \text{for experiments 1, 2}$$

$$T_{av} = a' + b'C_{vf} \quad (9) - \text{for experiments 3, 4}$$

The values of the coefficients of these equations are given in Table 2.

Table 2.

Coefficient	Experiment			
	1	2	3	4
$a$	$2.5 \cdot 10^{-4}$	$6.7 \cdot 10^{-4}$	—	—
$a'$	—	—	423	434
$b$	$0.6 \cdot 10^{-3}$	$1.11 \cdot 10^{-3}$	—	—
$b'$	—	—	25.6	27.1

The measurement results of the average volume temperatures and the temperature of fire gases ( $frg$ ) on the outgoing flow, recorded at the same time, are shown in Table 3.

Table 3.

Experiment							
1		2		3		4	
$T_{av}, K$	$T_{frg}, K$	$T_{av}, K$	$T_{frg}, K$	$T_{av}, K$	$T_{frg}, K$	$T_{av}, K$	$T_{frg}, K$
400	431	350	365	340	348	305	311
440	470	410	426	365	374	315	322
480	511	480	497	378	376	326	332
560	600	505	520	392	400	336	344
670	702	580	596	405	413	343	346

The measurement results of the wall temperatures of a mine/model and the average volume temperature at the same time are given in Table 4.

Table 4.

Experiment							
1		2		3		4	
$T_{av}, K$	$T_{wl}, K$	$T_{av}, K$	$T_{wl}, K$	$T_{av}, K$	$T_{wl}, K$	$T_{av}, K$	$T_{wl}, K$
471	333	235	167	125	87	120	85
623	396	305	194	218	139	210	134
673	417	345	215	220	137	225	140
823	485	401	236	337	196	310	182
923	532	452	267	367	351	351	202
1128	635	—	—	—	—	—	—

Time of fire spread. The experimentally obtained data to determine the time of the complete fire spread ( $f_s$ ) are presented in Table 5.

Table 5.

Experiment	$\ell_{tmax}, m$	$\tau_{fs}, \square$
1	45	1.21
2	30	1.08
3	45	1.16
4	35	1.02

Distances  $\ell_{tmax}$  in Experiments 3, 4 are determined taken into account the scale of modeling.

The dependences of fire growth time (in hours) on the length of the section at the end of which the maximum temperature is fixed as in the mine, as well as on the model of the tunnel, have got a linear character and can accordingly be expressed by empirical formulas:

$$\tau_{fs}^w = 0.81 + 0.009\ell_{tmax} \quad (10)$$

$$\tau_{fs}^t = 0.57 + 0.013\ell_{tmax} \quad (11)$$

Constant velocity of fire growth and the length of a zone of fire growth. The experiments have shown that the accelerated fire growth takes place in the first 2-17 minutes. Further, the velocity takes a constant value.

For its calculation, it is essential to know the distance from the seat of fire to that place, where the maximum temperature of fire gases is fixed and the time for the complete fire growth, excluding the time interval when its accelerated growth takes place.

These time intervals for the experiments 1,2,3,4, accordingly, were 1015, 240, 300 and 120 seconds. Taking this into account, the velocity of fire gases under the conditions of these experiments takes the following values:  $1.35 \cdot 10^{-2}$ ;  $8.2 \cdot 10^{-3}$ ;  $1.16 \cdot 10^{-2}$  and  $9.9 \cdot 10^{-3} m \cdot s^{-1}$  (at a ventilation flow rate of  $1 m \cdot s^{-1}$ ).

The dependence of a constant rate of fire growth on the velocity of the ventilation flow has been found having the following form for all experiments:

$$C_{fg} = C_{vf} / (a'' + b''C_{vf}) \quad (12)$$

The values of coefficients  $a''$ ,  $b''$ , are given in Table 6.

Table 6.

Coefficient	Experiments			
	1	2	3	4
$a''$	51.1	53.4	66.7	69.8
$b''$	23.0	68.5	19.5	31.2

Having known the constant velocity and the time of fire growth, according to the formula (7), the length of the fire growth zone was determined, that was 39, 21, 32, 24 m. for the experiments 1, 2, 3, 4, accordingly.

#### 4. Conclusions

As a result of the full-scale tests:

- The dependences of the medium-volume temperature of fire gases on the velocity of the ventilation flow were determined. Medium-volume temperatures and wall temperatures (lining) at the same time of fire growth were measured;
- The time of the full fire growth was determined – 1.02 – 1.21 hours. Empirical formulas were found for their determination;

- c) The constant velocity and length of the fire growth zone were determined. The dependence of the constant velocity of fire growth on the velocity of the ventilation flow was revealed. The coefficients being in the empirical formula were calculated. The length of the fire growth zone in the carried out experiments was 21 - 39 m.
- d) The velocity of fire gases was determined by the dynamic velocity pressure. It has been established that under various conditions to carry out full-scale experiments, the velocity of fire gases can increase up to 8.8 times.

## Acknowledgements

This work was supported by the Shota Rustaveli National Science Foundation (SRNSF) [Grant #217292, Title: "Hybrid fiber-reinforced polymeric composites with matrix strengthened nano,-ultra powders"].

## References

- Abashidze G, Chikhradze N. *The Description of Development of Exogenic Fire in Underground Structures*. Bull. Geor. Natl. Acad. Sci. 173, N 3, 2006, pp 537-539
- Characteristics and Behavior of Fire. Products of combustion and their effects on life safety* // Fire Protection handbook. 1969.-13-th-4-32
- Cioca L. I, Moraru R. I., *Explosion and/or fire risk assessment methodology: a common approach, structured for underground coalmine environments*, Archives of Mining Sciences, Volume 57, Issue 1, pp. 53-60, 2012
- Davidkin N. F., Esin V.M., Krivosheev I.N., *Smoke Pollution of Adjacent Areas and Building During Fires in Underground Construction. Fire-and-explosion hazard of substances and venting of deflagrations. Proceeding of the First International Seminar*. Moscow-1996, p.131-136
- G. S. Abashidze. *Proceeding of Academy of Sciences GSSR*, 122, 2, 1986, 361-363
- Haack A. 1992. *Fire Protection in Traffic Tunnels-Initial Findings from Large-scale Tests* // *Tunneling and Underground Space technology*, VOL. 7 (1992), No. 4 - p. 363-375
- Haukur Ingason. *Small Scale Test for a Road Tanker Fire Scenario. Fire Technology*, 1985. Boras, Sweden. Swedish National Testing and Research Institute, pp 3-20
- Ilias N., Lanchava O., Nozadze G. *Numerical modelling of fires in road tunnels with longitudinal ventilation system*. Calitatea, suppl. Supplement of Quality-Access to Success: Acces la Success; Bucharest, Vol. 18, Iss. S1, (Jan 2017): 77-80
- Koshmarov Yu. A. *Study of the fire in the building and its modeling. Abstracts of the Soviet-American seminar "fire development and its mathematical modeling"* (in Rus.), 1981, Tbilisi
- Kumar S., *Fire Development and Smoke Spread in Tunnels-Some Modeling Considerations*, p 379-394, Safety in Road and Rails Tunnels, First International conference Basel, Switzerland, 23 rd - 25 November 1992
- Lanchava O., Abashidze G., Tsverava D. *Securing fire safety for underground structures*. Calitatea, suppl. Supplement of Quality-Access to Success: Acces la Success; Bucharest, Vol. 18, Iss. S1, (Jan 2017): 47-50
- Lanchava O., Ilias N., Nozadze G. *Some problems for assessment of fire in road tunnels*. Calitatea, suppl. Supplement of Quality-Access to Success: Acces la Success; Bucharest, Vol. 18, Iss. S1, (Jan 2017): 69-72
- Mikkola E., Keski - Rahkonen O., Holmlund C., Loikkanen P., Ludvigson H. *Full Scale Fire Experiments in a Tunnel. Large Rock Caverns*. Proc. Int. Symp., Helsinki, 25-28 Aug. 1986, Vol. 3, Oxford e.a., 1987, 2007-2011
- Mine Test Chamber. "*Mining J.*", 1987, 308, N 7918, 39
- Moraru, R.I., Băbuț G.B., Cioca, L.I., Ragazzi, M., *Spontaneous combustion risk analysis in subsurface environments: carbon monoxide data processing tool*, Environmental Engineering and Management Journal, Volume 16, Issue 6, pp. 1317-1322, 2017



## Heat and hygroscopic mass exchange modeling for safety management in tunnels of metro

Omar Lanchava<sup>ab</sup>, Nicolae Iliăș<sup>c</sup>, Giorgi Nozadze<sup>a</sup>, Sorin Mihai Radu<sup>c</sup>

<sup>a</sup> G.Tsulukidze Mining Institute, Minelli Street, 7, 0177, Tbilisi, Georgia

<sup>b</sup> Georgian Technical University, Kostava Street, 77, 0175, Tbilisi, Georgia

<sup>c</sup> University of Petroșani, 20 Universității str., Petroșani 332006, Romania

---

### Abstract

Thanks to modern technologies of construction and operation of transport tunnels, it is assumed in the present work that drainage of water does not occur inside the membrane in the volume of reinforced coating of the tunnel and here takes place a non-stationary process of transfer of hygroscopic mass (moisture) together with a similar process of heat transfer between the ventilation stream and the surrounding mining massif. Thus, we have to deal only with the sorption mass content in the pores of the massif and the water in the explicit form in the tunnels can only be in exceptional cases as local sources and therefore, their influence on the ventilation flow should be considered separately. In addition, based on the principle of Onsager reciprocal relations, this article assumes that the heat flux is affected not only by the direct driving force-the temperature gradient, but also by the gradient of the mass transfer potential that is indirect in relation to this flow. Consequently, in the process of heat transfer is taken into consideration of the effect of Sore. Similarly, the mass (moisture) transfer is taken into consideration of the addition effect Dufour, when the cause of the mass transfer is not only the direct driving force - the gradient of the mass transfer potential, but also the indirect driving force in relation to this flow - the temperature gradient.

Keywords: Non-stationary heat and mass transfer, temperature gradient, mass transfer potential gradient, modeling.

---

### 1. Introduction

For the determination of changing of climatic parameters of the ventilation air of tunnels, it is necessary to considerate with naturally magnitudes of temperature and natural mass (moisture) transfer potential of surrounding rock massif. Due to seasonal fluctuations in the temperature and relative humidity of the atmospheric air, heat and mass transfer between the massif and the air is non-stationary. The nonstationary nature of the processes is more abundant by the formation of cooled zone and decreased moisture content zone in the massif around the tunnels. Therefore, the exchange of heat and matter between the massif and the ventilation flow occurs through the marked zones and the rate of marked exchanges decreases steadily over time.

Thus, the ventilation flow due to heat and mass transfer, through tunnel coating and liner, forms perturbed zones in the surrounding mining massif, which leads to a decrease in the natural values of the temperature and the mass transfer potential in these zones. As a result of this, the natural values of the marked physical quantities will be observed only in the depth of the massif. In classic papers non-stationarity considered by means of appropriate ratio when applied the natural temperature of the massif. For example works of (Shcherban et al., 1977), (Oniani, 1973), (Kuzin et al., 1979) and (Kremnev and Zhuravlenko, 1980). But non-stationary of heat and moisture transfer may be considered by means of dimensionless temperature and dimensionless mass transfer potential on the dividing surface of the "tunnel wall - airflow" and of stationary appropriate ratio of transfer. Among similar works it is necessary to note papers (Lanchava and Ilias, 2017; Băbuț et al. 2015), (Moraru et al, 2009; 2012), (Lanchava, 1982; 1985), (Petrilean, 2013) and (Petrilean et al., 2014; 2017). In this approach, the entire complexity of changing physical fields in a massif is, as it were, transferred to the surface of the tunnel and the variable values are the dimensionless temperature and the potential of mass transfer of the walls of the tunnel.

For the circular shape of the tunnel, hypsometrically located below the first waterproof layer, the scheme of the natural temperature fields and the mass transfer potential is shown in Fig. 1. The noted scheme is typical for tunnels located at great depth, in which the width of the cooled and drained zones increases with time. The equations of fields

of the temperature and of the mass transfer potential in surrounding rock massif, respectively, have the form  $t = f(R, \tau)$ ;  $\vartheta = F(R, \tau)$  where  $\tau$  is the time. For an infinite length of the cylindrical coordinate, the values of the temperature and the mass transfer potential take their natural magnitudes. Similar nonstationary heat and mass transfer processes are considered in (Lanchava, 1982; 1985).

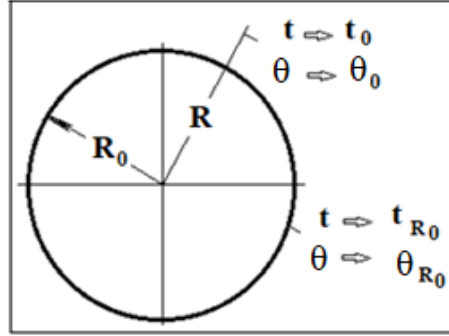


Fig. 1. Distributions of temperature and of mass (moisture) transfer potential on the tunnel surface and the surrounding rock massif on the tunnel axis:  $R$  - cylindrical coordinate;  $R_0$  - equivalent radius of tunnel; 0 and  $R_0$  indexes show the temperature and mass transfer potential values in the surrounding isotropic environments and on the dividing surface

As for the tunnels located at low depths, in particular transport tunnels and especially the tunnels of the metro, here the hygroscopic mass exchange behind the membrane in depth of massif does not occur, because the membrane is waterproof. Similar membranes are widely used in modern tunnelling. Thus, inside the membrane, within volume of the reinforced coating takes place moisture-equalizing. The mentioned volume has absorbed moisture from the air or gives moisture to the air depending on the season of the year. The moisture content of this volume is about the maximum hygroscopic index. Consequently, in the tunnels of the metro, non-stationary heat exchange takes place, during which the cooled zone in the massif spreads beyond the boundaries of the membrane. Mass transfer takes place only spread within a volume of reinforced coating.

## 2. Materials and methods

Non-stationary heat transfer coefficient for tunnels with reinforced coating is determined by formula

$$K_{\tau} = K_1 \bar{t} \quad (1)$$

where  $K_{\tau}$  - non-stationary heat transfer coefficient,  $W/(m^2 \cdot ^\circ C)$ ;  $\bar{t} = t(\tau, R_0)$  - dimensionless surface temperature of the tunnel, in parts of the one,  $0 \leq \bar{t} \leq 1$ ;  $K_1$  - coefficient of heat transfer from the massif to the ventilation flow, with consideration the influence of reinforced coating of the tunnel, which is determined by the formula

$$K_1 = \left( \frac{1}{\alpha} + \frac{\delta_1}{\lambda_1} \right)^{-1} \quad (2)$$

where  $\alpha$  - stationary heat transfer coefficient from surface of the tunnel,  $W/(m^2 \cdot ^\circ C)$ ;  $\delta_1, \lambda_1$  - respectively, the thickness of reinforced coating of the tunnel and the coefficient of thermal conductivity of the coating material, m;  $W/(m \cdot ^\circ C)$ .

Non-stationary mass transfer coefficient for tunnels with reinforced coating is determined by formula

$$K_m = K_2 \bar{\Theta} \quad (3)$$

where  $K_m$  - non-stationary mass transfer coefficient,  $kg.mol/(J.m^2.s)$ ;  $\bar{\Theta} = \Theta(\tau, R_0)$  - dimensionless mass transfer potential of the tunnel surface, in parts of the one,  $0 \leq \bar{\Theta} \leq 1$ ;  $K_2$  - coefficient of mass transfer from the massif to the ventilation flow, with consideration the influence of reinforced coating of the tunnel, which is determined by the formula

$$K_2 = \left( \frac{1}{\alpha_m} + \frac{\delta_{m1}}{\lambda_{m1}} \right)^{-1} \quad (4)$$

where  $\alpha_m$  - stationary mass transfer coefficient from surface of the tunnel,  $kg.mol/(J.m^2.s)$ ;  $\lambda_{m1}$  - the coefficient conductivity of mass transfer potential of the coating material,  $kg.mol/(J.m.s)$ .

Hygroscopic mass transfer potential can be calculated with the following formula (Tsimmermanis, 1971)

$$\Theta = RT \ln \varphi \quad (5)$$

where  $\Theta$  - hygroscopic mass transfer potential, J/mol;  $R$  - universal air constant; J/(mol.K),  $R = 8.3144$ ;  $T$  - absolute temperature, K;  $\ln$  – symbol of natural logarithm;  $\varphi$  – equilibrium relative humidity of air, balanced with a sorbent,  $0 \leq \varphi \leq 1$ . In which, apart from explained dimensions  $\Theta$  - hygroscopic mass transfer potential, J/mol;

In this formula,  $\ln \varphi = 0$ , when  $\varphi = 1$ , in the rest of the cases, for hygroscopic area  $\varphi < 1$  and value of the potential determined by the formula (5) is of negative sign.

The potential calculated with formula (5) is acceptable in order to evaluate hygroscopic mass transfer in mining massive. As commonly known, increasing temperature causes decrease of van der Waals powers of sorption field, which is resulted in decrease of isothermal specific mass factor (this factor of the capillary-porous body  $c_m = 0$  on the critical temperature for water that equals of 647K, because at this temperature water vapor sorption is impossible). In such a case, the power of sorption field and its characteristic size – transfer potential should be necessarily decreased. Formula (9) permits to establish inversely proportional addition between  $\Theta$  and  $T$  as well  $c_m$ ,  $T$  couples, while between  $\Theta$ ,  $c_m$  couples it arises directly proportional addition. This not contradicts neither to existing theoretical views nor to experimental results of determining isothermal specific mass factor.

Calculating mass transfer potential for mining massif is also possible with the formula offered below:

$$\Theta = RT \ln \left( \frac{U}{U_{\max}} \right) \quad (6)$$

where  $U$  - hygroscopic moisture content of mining massif on the temperature  $T$ , kg/kg;  $U_{\max}$  – maximum hygroscopic moisture content of mining massif on the same temperature, kg/kg.

### 3. Results and discussion

#### 3.1. Thermophysical and Mass-physical characteristics of rocks

Thermophysical and mass-physical coefficients of rocks (or soils) ( $\lambda$ ,  $a$ ,  $c$ ,  $\lambda_m$ ,  $a_m$ ,  $c_m$ ,  $\delta_\theta$ ,  $\gamma_0$ ), which are related to each other with a known law (Dzidziguri et al., 1966)

$$\lambda = ac\gamma_0, \quad (7)$$

where  $\lambda$  is the heat conductivity coefficient of the rock, W/(m.K);  $a$  - coefficient of thermal diffusivity of the rock, m<sup>2</sup>/s;  $c$  - specific heat, J/(kg.K);  $\gamma_0$  - the rock density, kg/m<sup>3</sup>.

Mass-physical characteristics of rocks are related to each other by analogical formulation, thus confirming the analogy of these processes (Lanchava, 1998)

$$\lambda_m = a_m c_m \gamma_0 \quad (8)$$

where  $\lambda_m$  mass conductivity factor of the rock, kg.mol/(J.m.s);  $a_m$  – the mass transfer potential diffusivity factor for the rock, m<sup>2</sup>/s;  $c_m$  - the isothermal specific mass factor for the rock, mol/J.

In the case of ventilation of tunnels, thermal exchange in a binary system "mining massif - ventilation flow" is not only under the influence of the temperature gradient but also of the gradient of mass transfer potential. The ultimate thermal flow consists of two elements: one is caused by the temperature gradient and the second by mass transfer potential gradient. Similarly, the mass flow consists of two elements. In this case the direct driving force is a gradient of mass transfer potential, and the temperature gradient is additional driving force. This is reflected in the mathematical expression of the principle of Onsager (1931) reciprocity that express the equality of certain ratios between flows and forces in not equilibrium thermodynamic systems

$$J_i = \sum_{k=1}^n L_{ik} X_{k(i=1,2,\dots,n)} \quad (9)$$

where  $J_i$  is thermodynamic driving forces (temperature and mass transfer potential) that generated both flows;  $L_{i,k}$  - the physical environment in which energy or substance is transmitted (in our case thermophysical and Mass-physical characteristics of rocks);  $X_k$  - potential gradients that originated streams.

For the thermodynamic driving forces, such are a gradient of thermodynamic temperature and a gradient of mass transfer, the principle of Onsager's reciprocity has a form

$$J_1 = L_{11}X_1 + L_{12}X_2 \quad (10)$$

$$J_2 = L_{21}X_1 + L_{22}X_2 \quad (11)$$

where  $J_1$  is a thermal flow density, which is determined by the Fourier law in a private case;  $J_2$  - the mass flow density, which is determined by the Fick's law or Luykov law, in the private case, in according what is the nature of the forces  $X_2$ , the gradient of concentration, or the mass transfer gradient.

### 3.2. Criteria for the similarity of heat and mass-exchange processes

Equations (10), (11), for the circuit depicted in Fig. 1, in the case of an isotropic and homogeneous mining massif, have the following differential form (Luikov, 1978)

$$\frac{\partial t}{\partial \tau} = a\Delta^2 t + \varepsilon r \frac{c_m}{c} \frac{\partial \Theta}{\partial \tau} \quad (12)$$

$$\frac{\partial \Theta}{\partial \tau} = a_m \Delta^2 \Theta + a_m \delta_\theta \Delta^2 t \quad (13)$$

where  $\varepsilon$  - criterion for the phase transition of moisture in the mining massif. The rest of the symbols were determined previously.

Initial and boundary conditions have the form

$$\tau = 0, R = R_0: t_{(R_0,0)} = t_0, \Theta_{(R_0,0)} = \Theta_0 \quad (14)$$

$$\tau > 0, R = \infty: t_{(R,\tau)} = t_0, \Theta_{(R,\tau)} = \Theta_0 \quad (15)$$

$$\tau > 0, R = \infty:$$

$$-\lambda \frac{\partial t}{\partial R} + \alpha(t_k - t_h) + \alpha_m r(\Theta_k - \Theta_h) = 0 \quad (16)$$

$$-\lambda_m \frac{\partial \Theta}{\partial R} - \lambda_m \delta_\theta \frac{\partial t}{\partial R} + \alpha_m(\Theta_k - \Theta_h) = 0 \quad (17)$$

where  $t_k, \Theta_k$  - temperature and mass transfer potential of the walls of tunnel,  $^0C$ , j/mol;  $t_h, \Theta_h$  - the same for ventilation flow. The rest of the symbols were determined previously.

From these equations, initial and boundary conditions follow criteria for the similarity of heat and mass-exchange processes: Bio, Fourier, Kosovich, mass transfer criteria Fourier, Bio and Posnov that respectively have the form

$$Bi = \frac{\alpha R_0}{\lambda}; Fo = \frac{a\tau}{R_0^2}; Ko = \frac{rc_m}{c} \frac{\Delta \Theta}{\Delta t} \quad (18)$$

$$Bi_m = \frac{\alpha R_0}{\lambda}; Fo_m = \frac{a_m \tau}{R_0^2}; Pn_m = \delta_\theta \frac{\Delta t}{\Delta \Theta} \quad (19)$$

where  $\tau$  time, s;  $R_0$  - equivalent radius of the tunnel, m;  $\Delta t$ ,  $\Delta \theta$  - temperature and potential increments respectively;  $\delta_\theta$  - thermal gradient factor showing additional mass transmission in the system in the form of Soret effect, J/mol. K;.. The rest of the symbols were determined previously.

Equation (16) is an expression of the energy conservation law for the mentioned system. To analyse it, application of a new similarity criterion is needed. According to the  $\pi$ -theorem, in this formula the number of dimensional quantities, primary dimensions and dimensionless quantities (similarity criteria) are 9, 5 and 4, respectively (Kutateladze, 1982). These criteria are the dimensionless temperature, the Bio and Posnov criteria. The definition of a dimensionless temperature is given below. We note that, according to the  $\pi$ -theorem, there must be four criteria, but there are only three of them.

$$\frac{\Delta_\tau t}{\Delta_R t} = t_{(R,\tau)} = \frac{t - t_2}{t_0 - t_2} \quad (20)$$

where  $t_0$  - natural temperature of mining massif,  $^0C$ .

After insertion of limited proportional quantities according to L'Hopital's rule and multiplication by  $R/\lambda \Delta_\tau t$ , equation (16) will transform as

$$\frac{\Delta_\tau t}{\Delta_R t} = \frac{\alpha R}{\lambda} + \frac{\alpha_m r R}{\lambda} \frac{\Delta_\tau \theta}{\Delta_\tau t} \quad (21)$$

For the tunnel wall, i. e. when  $R = R_0$  after simple transformations equation (21) will get the following form

$$\frac{\Delta_\tau t}{\Delta_{R_0} t} = Bi + La \frac{Bi}{Pn_m} \quad (22)$$

where a new criterion is introduced

$$La = \frac{\delta_\theta \alpha_m r}{\alpha} \quad (23)$$

As it is seen from equation (22), dimensionless temperature of a tunnel wall is combination of the appointed complexes. Thus, criterion expressed by formula (23) is the fourth dimensionless complex that is necessary for the process analysis according to  $\pi$ -theorem.

The new criterion relates thermal resistance  $1/\alpha$  with mass transfer analogical resistance  $1/\alpha_m$  within the limits of corresponding boundary layers. Thus, estimation of the ventilation air flow by it appears to be possible as both of those values are the current characteristics.

The first impression is that the same result can be obtained by Lewis, Kosovich, or Posnov criteria separately. This is not quite correct as each of them taken separately characterizes just the massif showing only a rate of increase of cooled and dried up layers thicknesses.

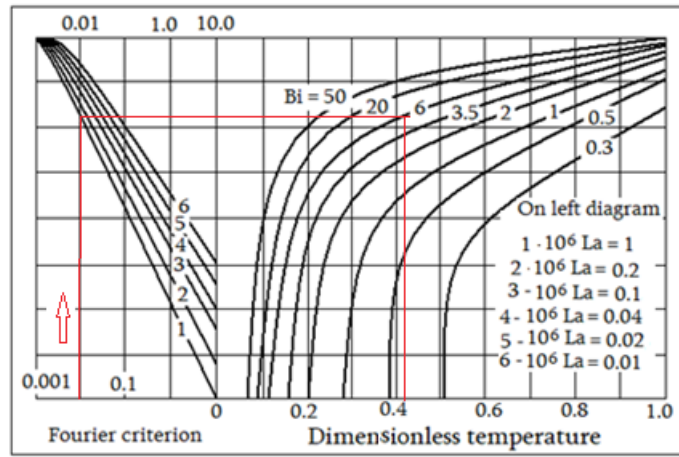


Fig. 2. Changing of dimensionless surface temperature of the tunnel  $\bar{t} = f(Fo, Bi, La)$

use the nomogram as follows according to the red lines (beginning on the left diagram):  $Fo = 0.01$ ;  $10^6 La = 1$ ;  $Bi = 6$ ; Dimensionless temperature  $\bar{t} = t(\tau, R_0) = 0.42$

In fact, temperature gradient always causes additional mass flow and vice versa – gradient of mass transfer potential causes additional thermal current, but there are cases in practice, when consideration of these additional currents is not necessary for calculation of ventilation flow temperature, mass transfer potential and relative humidity.

The said is corroborated by the critical value of the new criterion  $10^6 La = 1$ . Consideration of interference of these two processes for solution of multiparametric tasks is needed when this equality fails.

Using formula (1) and the dimensionless temperature from Fig. 2, it is possible to determine the non-stationary heat transfer coefficient with or without additional heat flow and accordingly thermal calculation.

#### 4. Conclusions

Thus, heat and mass fluxes in the two-component system "mountain massif-ventilation air" are the result of the influence of two gradients-the temperature potential and the mass transfer potential. The additional threads initiated by the effects of Sore and Dufour tend to amplify the main flows, but in practice, there is a case where there is no need to consider the effect of additional flows. Based on the analysis of processes, the criteria that determine their numerical values show that accounting for additional flows of Sore and Dufour is mandatory. Marked effects can be ignored when  $10^6 La = 1$ . By means of the presented results can definite of non-stationary heat transfer coefficient for any cases of mentioned processes.

#### Acknowledgements

This work was supported by Shota Rustaveli National Science Foundation (SRNSF) [Grant number 216968, Project title "Prevention methods development against aerosol terrorism for ventilation of Tbilisi subway"].

## References

- Băbuț, G.B., Moraru, R.I., Cioca, L.I., *Operational categorization and classification of the malevolent acts for their integration in the risk assessment process of the major accidents*, Quality - Access to Success, Volume 16, Issue 147, pp. 85-91, (2015).
- Dzidziguri A.A., Duganov G.V., Oniani S.I., Sarichev R.A., Kukharev V.N., *Teplofizicheskie svoistva gornikh porod i metodi ikh opredelenia*. Tbilisi, Mecniereba, (1966), (in Russian).
- Kutateladze C. C., *Analiz Podobiya v Teplofizike*, Novosibirsk, (1982), (in Russian).
- Kuzin V.A., Velichko A.E., Khokhotva N.N., Iakovenko A.K., Bodnia S.F., Frolov M.A., Fandeev M.I., Filimonenko V.T., Krivoruchko A.M., Medvedev B.I., Stukalo V.A., Zhuravlenko V.I., Shcherban A.N., Cherniak V.P., Malashenko E.N., Zimin L.B., Matskovaia A.G., Braicheva N.A., Oniani S.I., Lanchava O.A., Diadkin I.D., Shuvalov I.V., Gendler S.G., *Edinaia metodika prognozirovania temperaturnich uslovii v shakhtach* (Reference book), Makeyevka (Donbass), (1979), (in Russian).
- Lanchava O.A., Heat and mass exchange in permanent mine workings. *Journal of Mining Science* **1**(6), (1982).
- Lanchava O.A., Heat and mass exchange in newly driven mine workings. *Journal of Mining Science* **1**(5), (1985).
- Lanchava O.A., *Hygroscopic heat and mass transfer in underground structures*, GTU, Tbilisi, (1998), (in Georgian).
- Lanchava O.A., Ilias N., Some issues of thermal calculation of ventilation air for the metro. *Journal of Engineering Sciences and Innovation* **2**(2), AGIR Publishing House, (2017).
- Luikov A.V., *Teplomassoobmen* (Reference book), Moscow, (1978), (in Russian).
- Moraru, R.I., Băbuț, G.B., Cioca, L.I., *Knowledge Based Hazard Analysis Guidelines for Operational Transportation Projects*, Proceedings of the 15th International Conference the Knowledge Based Organization: Management, Volume 2, pp. 117-122, Sibiu, Romania, 26-28.11. (2009).
- Moraru, R.I., Cioca, L.I., *Operational safety measures in human-machine systems: an overview*, Proceedings of the 18<sup>th</sup> International Conference - The Knowledge-Based Organization: Management and Military Sciences - KBO 2012, pp. 86-91, Sibiu, Romania, 14-16.06. (2012).
- Oniani S.I., *Teplovoi rezhim glubokikh shakht pri slozhnom pelefepoverkhnosti*. Tbilisi, (1973), (in Russian).
- Oniani S.I., Lanchava O.A., Ksovreli I.R., O vlagofizicheskikh svoistvakh gornikh porod. *Ugol Ukraini*, **44**(4), (1984), (in Russian).
- Onsager L., Reciprocal Relations in Irreversible Processes, *I*, *Phys. Rev.* **37**, (1931).
- Petrilean D.C., Mathematical Model for the Determination of the Non-Stationary Coefficient of Heat Transfer in Mine Works. *The 19th American Conference on Applied Mathematics (AMERICAN-MATH '13)*, Cambridge, MA, USA, (2013).
- Petrilean D.C., Stanilă S., Irimie S.I., Study of variable heat exchange between a thickness limited cylindrical pipe and the rock massif for application in mine environment. *Environmental Engineering and Management Journal*, **13**(6), (2014).
- Petrilean D.C., Stanilă S., Dosa I., A mathematical model for the determination of the dimensionless heat flux with application in mine environment. *Environmental Engineering and Management Journal*, **16**(6), (2017).
- Tsimmerman L.B., *Termodinamicheskie i perenosnye svoistva kapillarno-poristikh tel*, (1971), (in Russian).

# Dynamics of spread of fire-related harmful factors in metro tunnels during a forced stoppage of the metro train

Giorgi Nozadze\*

\*LEPL G. Tsulukidze Mining Institute, Tbilisi 0186, Georgia

## Abstract

The present work deals with emergency situations which develop as a result of 30 MW-magnitude fires that may occur for various reasons within the metro (subway) tunnel infrastructure. The article will produce numerical modelling of the emergency situation within the PyroSim 2016 programme environment. It will offer a base model of the emergency situation for the following tunnel geometry: cross-sectional area of the tunnel – 20 m<sup>2</sup>; length of the tunnel – 800 m; volumetric efficiency of the tunnel – 0,375; length of the metro train – 80 m; cross-sectional area of the train – 7.5 m<sup>2</sup>. The article will explore the changing dynamics of the harmful factors (temperature, carbon monoxide, carbon dioxide and oxygen concentration levels) which develop in portals along the tunnel as a result of fires. The boundary conditions for various ventilation flows will be examined. We will study the effect of the location of the train and the fire on the dynamics of spread of harmful factors as a result of stoppage of the train inside the metro tunnel. The modelling process will determine the required time parameters for safe self-evacuation in an emergency situation. It can be used for the quick planning and implementation of emergency assistance activities.

**Keywords:** Metro tunnel; fire, Harmful factors; numerical modelling.

## 1. Introduction

Underground transport (metro) represents the fastest-growing transport network in global megalopolises. The metro has a history of approximately 150 years. The total length of underground metro networks across the world is 15, 000 km, of which 5,000 km have been constructed during the past 15 years. Existing networks are being expanded and reconstructed, while elsewhere, new subway transport centres are being established. Security of the underground transport system is particularly sensitive with regards to fire safety (Moraru et al, 2013; Moraru et al, 2017). This is primarily due to the shortage of evacuation options during fires in the metro, as well as the difficulty of the evacuation process scenario. Statistics of the main causes of fire in the metro (Long Poon and Richard Lau, 2007; Moraru and Babuț, 2014) is presented in the form of a circle diagram (see Fig. 1).

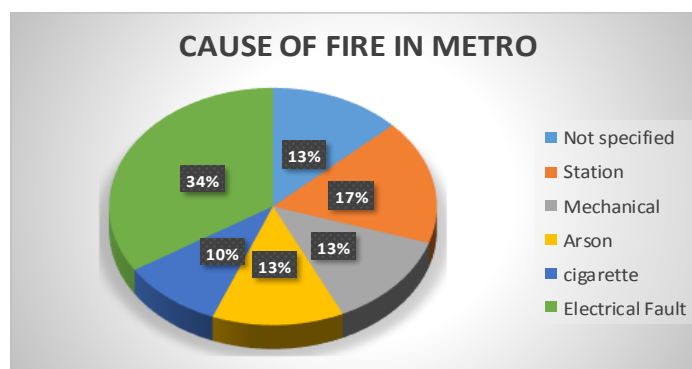


Fig. 1. Statistic data of the causes of fires in the metro

Based on the given statistics, approximately 17% of the metro fires occur at the stations and in areas adjacent to the stations, while the remaining 83% are accounted for by metro tunnels, where fire safety and evacuation activities are more difficult to implement than at the stations.

These instances usually lead to the stoppage of the metro train and the start of the self-evacuation process towards a free portal inside the tunnel.

During the last 30-35 years, there have been several cases of catastrophic fires occurring in the subway and funicular transportation systems. Although these were not particularly powerful fires, they all had disastrous results. For example, the Baku Metro fire in Azerbaijan killed 337 people in 1995, while 155 people died in Kaprun (Austria) in 2000, and 198 people in Daegu (South Korea) in 2003.

The aforementioned cases have all got several common characteristics: The materials involved in the fires were characterised by flammability and high toxicity of the substances released during the fire; The metro train was forced to come to halt inside the tunnel (Baku, Kaprun), or did not leave the station (Daegu);

The majority of the victims were poisoned by toxic gases.

- The complexity of the causes of fire.

- The absolute majority of metro systems use a high-voltage electrical power system. Statistics show Fig. 1. that electrical faults constitute the most common cause of fires today.

Fires in the metro can be subdivided into the following two categories:

- Fires in the metro's power supply infrastructure;
- Fires in the metro's metro train.

In present article we study fire in metro's power supply infrastructure.

## 2. Task of numerical modelling

### 2.1 Initial Conditions

In the present study we do numerical modelling of possible fire scenarios in the metro's power supply system, using the tunnels of the Tbilisi metro as an example. The geometric data of the tunnel and the metro train is presented below:

- Length of the tunnel –  $L_t = 800$  m; cross-sectional area of the tunnel –  $S_t = 20$  m<sup>2</sup>; length of the train –  $L_{tr} = 80$  m; cross-sectional area of the train –  $S_{tr} = 7.5$  m<sup>2</sup>; the location of the halted train is measured from the left-hand portal, using the coordinates  $X_{tr,1}$  and  $X_{tr,2}$ , whereby  $X_{tr,2} = X_{tr,1} + L_{tr}$ ; fire location –  $X_F$ ; location of the tunnel air shaft –  $X_s = 400$  m from the left-hand portal; cross-sectional area of the shaft –  $S_i = 1, 4, 9$  m<sup>2</sup>; surface area of the burn –  $S_F$ ; general formula for the burn reaction type –  $C_xO_yH_zN_r$ , the carbon compounds used in the high-molecular electric isolation material are modelled on the simple reaction of burning polyurethane, with the average carbon monoxide share of 0.2 g/g (Sean Thomas McKenna and Terence Richard Hull, 2016). The location of the halted train is measured from the left-hand portal, and the modelled cases are:  $X_{tr,1} = 202$  m, 302 m, 351 m, 402 m, 502 m, 602 m. The fire source is located at the  $X_F = 700$  m mark from the left-hand portal. The modelled cases are classified as follows, depending on the position with respect to the air shaft (see Fig.2.):

$$\begin{aligned}
 & - X_{tr,1}, X_{tr,2} < X_s < X_F; & X_{tr,1} = 202 \text{ m}, 302 \text{ m} \\
 & - X_{tr,1} < X_s < X_{tr,2} < X_F; & X_{tr,1} = 351 \text{ m}, \\
 & - X_s < X_{tr,1}, X_{tr,2} < X_F & X_{tr,1} = 402 \text{ m}, 502 \text{ m}, 602 \text{ m}
 \end{aligned}
 \tag{1}$$

### 2.2 Boundary Conditions

The flow of heat from the fire and the boundary conditions for the ventilation flow are presented in Fig. 2.

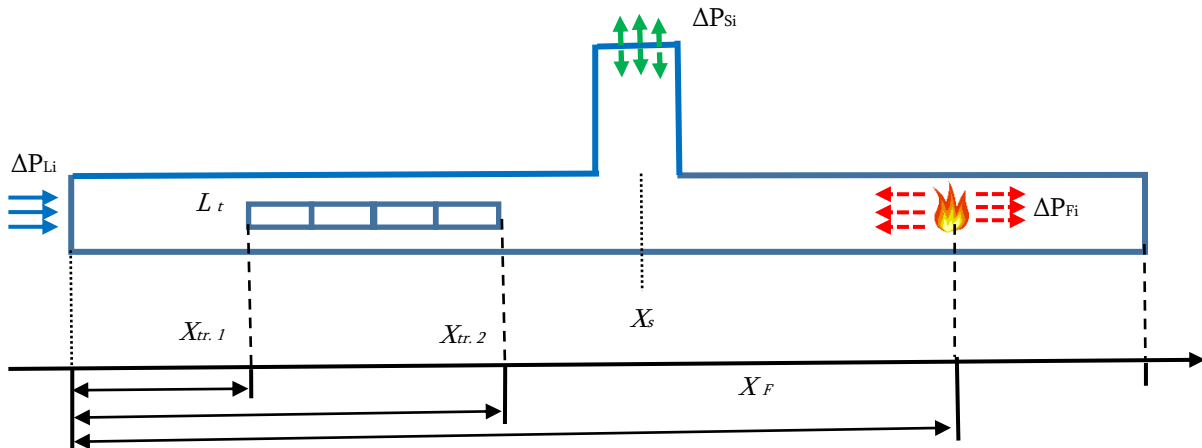


Fig. 2. An emergency situation model of a forced stop of a train during infrastructural fires in a subway tunnel.



The dynamic pressure from the ventilation flow in the left-hand portal is modelled as the difference in pressure between the portals –  $\Delta P_{Li}$ .

A numerical model was established within the set task. Numerical modelling was used to study the dynamics of spread of harmful factors from heat flow  $\Delta P_{Fi}$  which stems from the fire. Boundary conditions created by additional dynamic flows at one of the portals and the outer cross-section of the intermediate air shaft inside the metro tunnel have also been examined –  $\Delta P_{Li} = \pm 1, \pm 10, \pm 100$  Pa,  $\Delta P_{Si} = \pm 1, \pm 10, \pm 100$  Pa. Numerical modelling time – 300 sec, 1200 sec, 2400 sec.

The effect of the location of the halted train on the dynamics of the harmful factors has been studied. In order to obtain quick and optimal results from multiparameter numerical modelling, we have introduced the ‘base model concept,’ (Ilias at all, 2017) which involves forming the worst possible starting and boundary conditions for the given geometric parameters of the tunnel, and obtaining the worst spatial scale and time scale for the harmful factors.

The harmful factors examined in the present study are the increase in carbon monoxide and carbon dioxide concentration levels, decrease in oxygen levels, as well as the dynamics of temperature distribution in the metro tunnel in case of a 30 MW-magnitude fire. For the correct formulation of the problem of the distribution of the temperature harmful factor, it will be necessary to consider the influence of the surrounding tunnel wall. This can be taken into account in the “base model” with the help of the technology proposed in the articles (Lancava, 1982,1985)

Detectors are located along the symmetric interface of the tunnel’s cross section, at a height of  $Z=1.5$  m from the tunnel bottom, at 100 m intervals.

Clearly, the worst possible situation applies to fires of the maximum strength required by technical regulations (30 MW), whereby the train is located at a short distance from the fire source (in our case, 602 m from the left-hand portal), and the cross section of the 10 m tall air shaft is minimal ( $1 \text{ m}^2$  in the case of our model). See Fig. 3

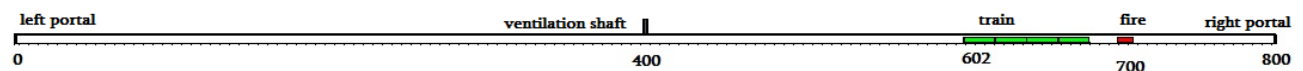


Fig.3. The Geometry data of ‘base model’ of metro tunnel in Pyrosim software.

Results of numerical modelling, displaying the dynamics of each harmful factor in time for the ‘base model,’ are shown below.

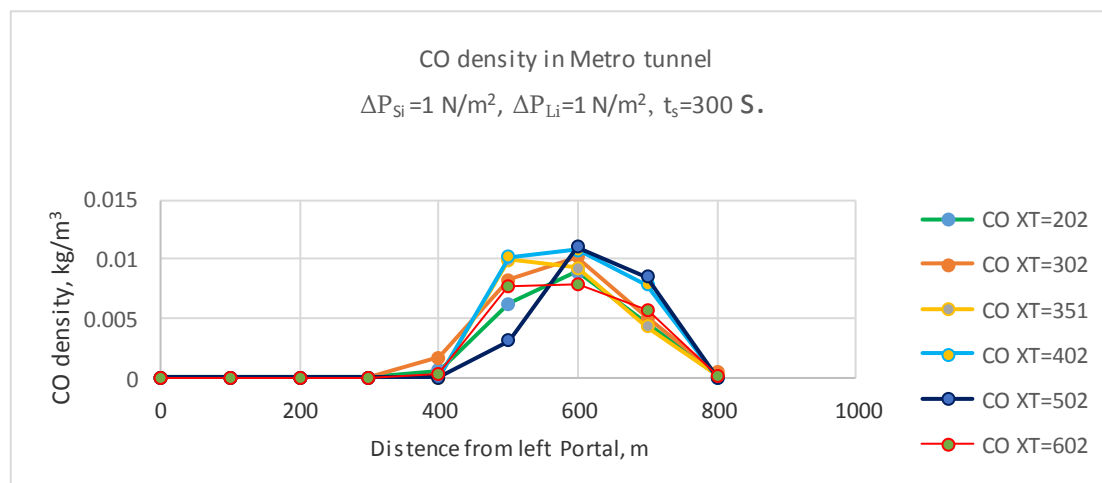


Fig. 4. Dependence of distribution of carbon monoxide concentration in the tunnel of the subway on the forced stop location of train. (HRR 30 MW, height  $Z = 1.5$  along the tunnel, simulation time 300 seconds)

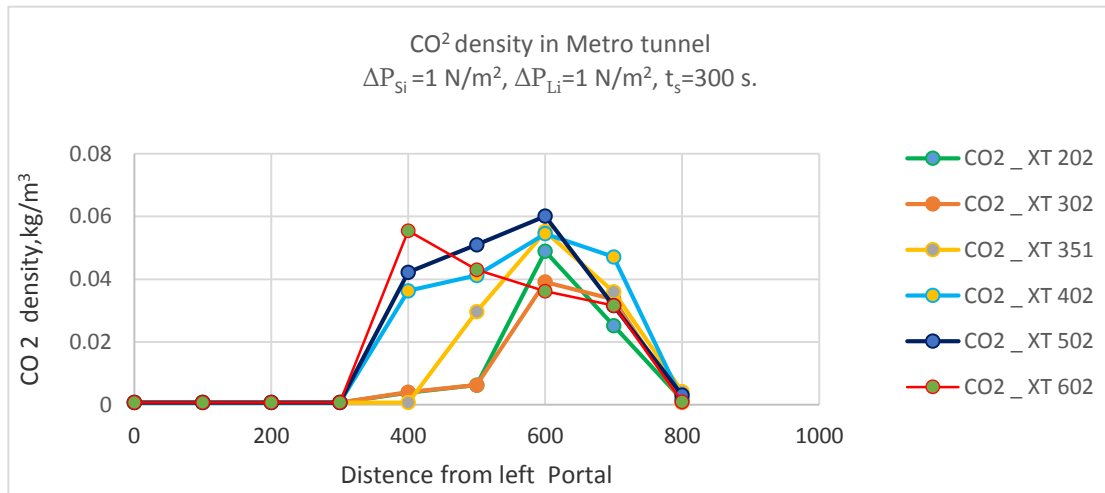


Fig. 5. Depends of distribution of carbon dioxide concentration in the tunnel of the subway on the forced stop location of train. (HRR 30 MW, height  $Z = 1.5$  along the tunnel, simulation time 300 seconds)

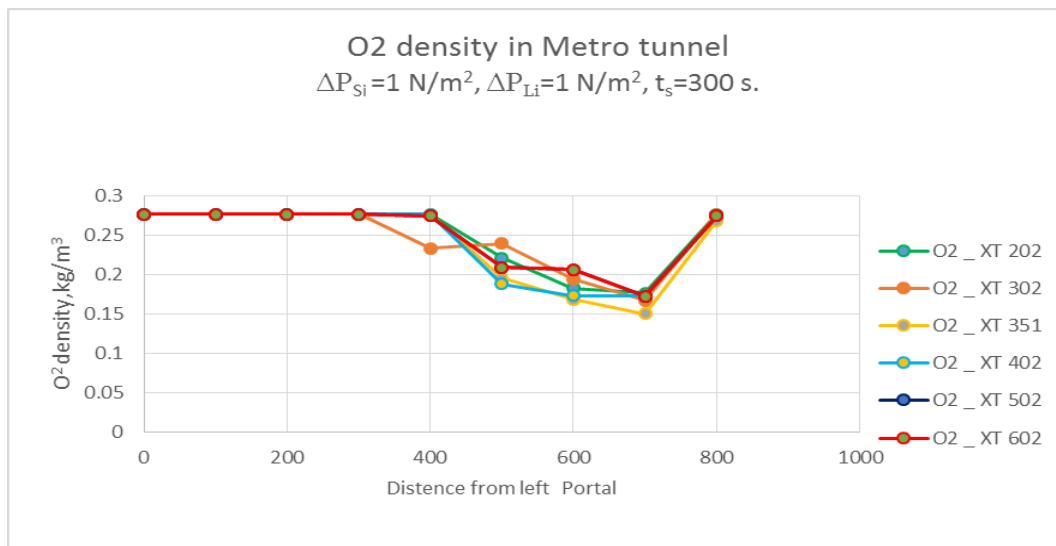


Fig. 6. Depends of distribution of oxygen concentration in the tunnel of the subway on the forced stop location of train. (HRR 30 MW, height  $Z = 1.5$  along the tunnel, simulation time 300 seconds)

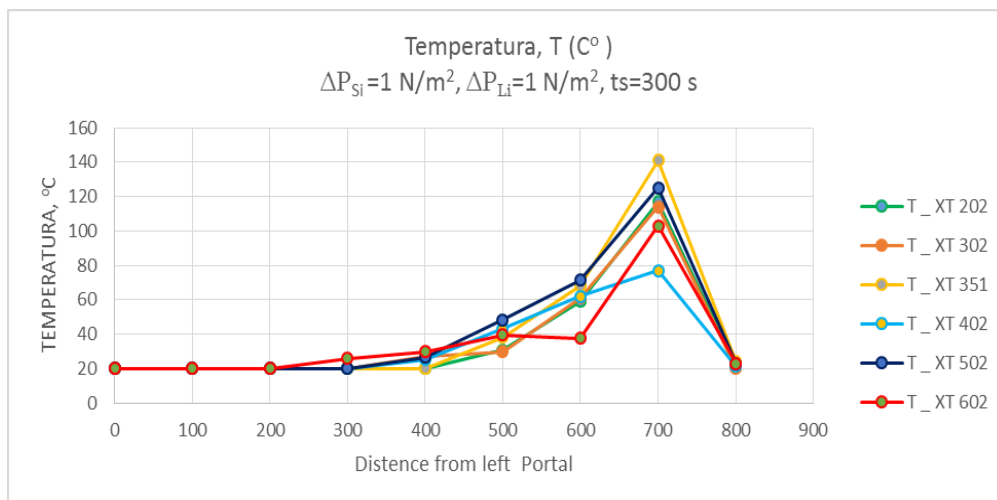


Fig. 7. Depends of distribution of Temperature in the tunnel of the subway on the forced stop location of train. (HRR 30 MW, height  $Z = 1.5$  along the tunnel, simulation time 300 seconds)

We examine a situation where the metro tunnel ventilation system becomes disabled, which is modelled on the boundary conditions for the 'base model' – through the total minimal increase of the natural dynamic pressure on one of the portals ( $\Delta P_{Li} = \pm 1 \text{ n/m}^2$ ), and the total dynamic pressure increase on the outer cross section of the air shaft ( $\Delta P_{Si} = \pm 1 \text{ n/m}^2$ ). For the Basic model, the process of changing the spatial scale of the harmful factors along the tunnel was studied. time of modeling  $t = 300 \text{ s}, 1200 \text{ s}, 2400 \text{ s}$ . The results presented on the Fig. 9-12

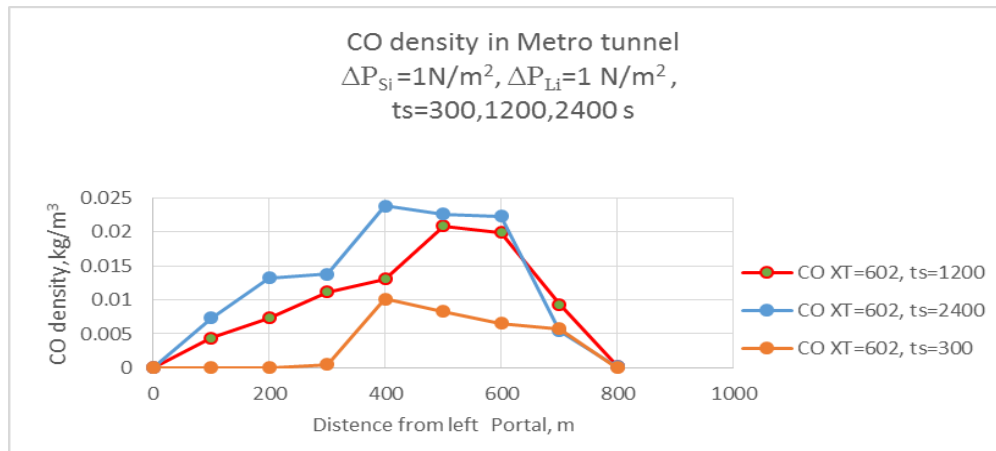


Fig.8. Dynamics of changes the spatial scale of concentration increase of carbon monoxide along the tunnel. The simulation time is  $ts = 300 \text{ s}, 1200 \text{ s}, 2400 \text{ sec}$ .

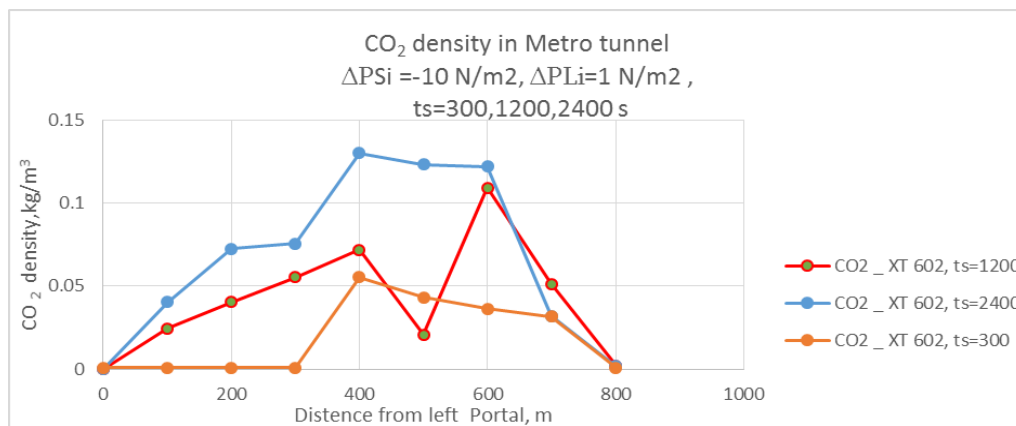


Fig. 9. Dynamics of changes the spatial scale of concentration increase of carbon dioxide along the tunnel. The simulation time is  $ts = 300 \text{ s}, 1200 \text{ s}, 2400 \text{ sec}$ .

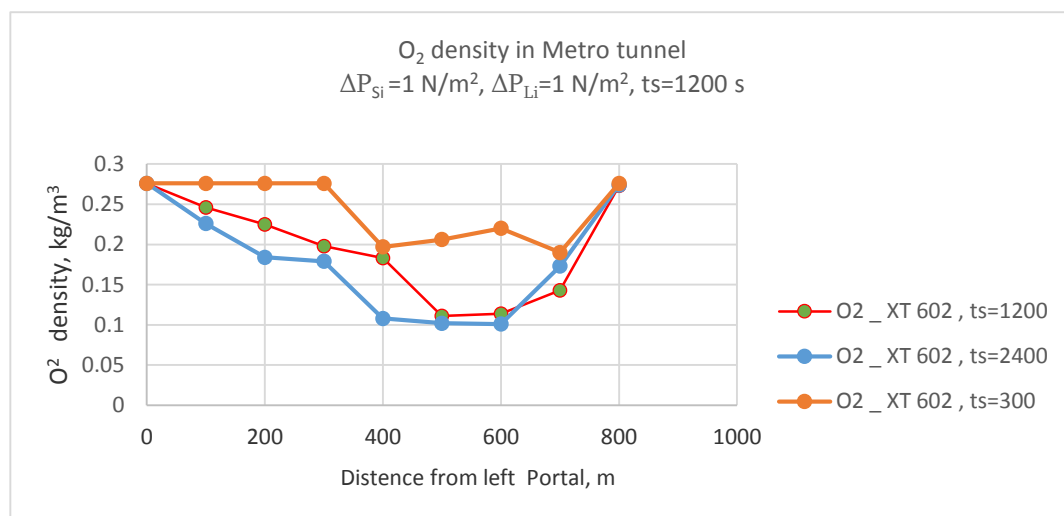


Fig. 10. Dynamics of changes the spatial scale of concentration decrease of Oxygen along the tunnel. The simulation time is  $ts = 300 \text{ s}, 1200 \text{ s}, 2400 \text{ sec}$ .

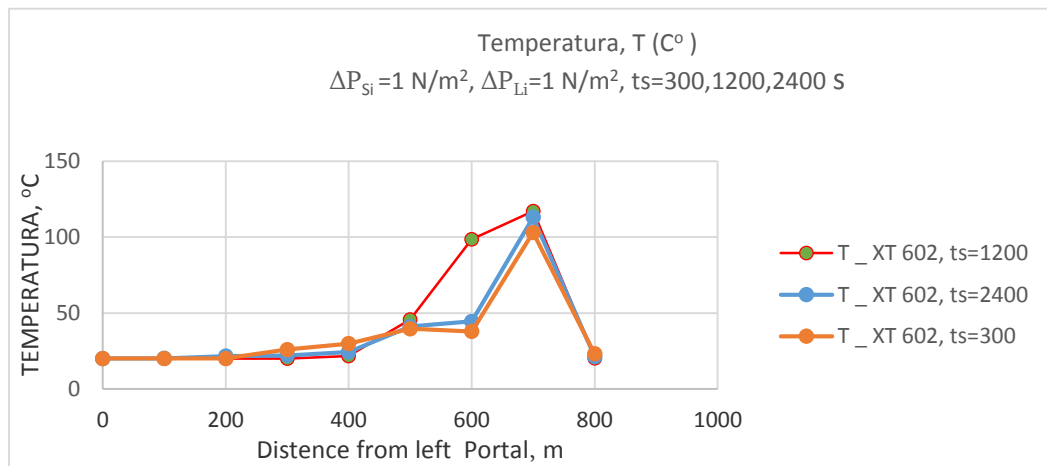


Fig.11. Dynamics of changes the spatial scale of Temperature along the tunnel. The simulation time is  $t_s = 300 \text{ s}, 1200 \text{ s}, 2400 \text{ sec}$ .

## Results

Results of the numerical experiments allow us to produce a practical assessment of spatial and time distribution of the harmful factors during the realisation of various boundary conditions. The test quantity of toxic and/or asphyxiants gases is their concentration level in the tunnel space, while the thermal harmful factor is represented by the average gas temperature along the tunnel.

- The modelling of the emergency situation caused by fire inside the metro tunnel is carried out on the basis of the 'base model,' which accounts for the numerical realisation of the worst possible scenario of creation and spread of harmful factors based on the existing tunnel geometry, as well as initial and boundary conditions;
- It is shown that the dynamics of spread of harmful factors are not significantly affected by the location of the halted train, when the volumetric efficiency of the tunnel's cross section is  $\alpha=0,375$ ;
- In case of 30 MW-magnitude fires, the spread of toxic and asphyxiant gases occurs over almost 300 m in 5 minutes, under the boundary and initial conditions that are realized in the base model. The spatial scale of these factors is characterised by a tendency of growth.
- The danger zone of the temperature factor is quickly stabilised. Its spatial boundary is located within a distance of 100-150 m from the fire source, on both sides of the tunnel.

## Acknowledgements

This work was supported by the Shota Rustaveli National Science Foundation (SRNSF) [Grant #216968].

## References

- Ilias N., Lanchava O., Nozadze G. Numerical modelling of fires in road tunnels with longitudinal ventilation system. *Calitatea, suppl. Supplement of Quality-Access to Success: Acces la Success; Bucharest, Vol. 18, Iss. S1, (Jan 2017): 77-80*
- Long Poon and Richard Lau – *Fire Risk in Metro Tunnels and Stations* – International Journal of Performability Engineering, Vol. 3, No. 3, July, 2007, pp. 355 – 368.
- Lanchava O.A., Heat and mass exchange in permanent mine workings. *Journal of Mining Science* 1(6), 87-92, (1982).
- Lanchava O.A., Heat and mass exchange in newly driven mine workings. *Journal of Mining Science* 1(5), 99-104, (1985).
- Moraru, R.I., Băbuț, G.B., *Research on methane emission mechanism and pattern in a longwall coal face at Livezeni colliery*, Proceedings of the 14th International Multidisciplinary Scientific Geoconference - SGEM 2014, Volume III, pp. 497-504, Albena, Bulgaria, 17-26.06 (2014).
- Moraru, R.I., Băbuț, G.B., Cioca, L.I., *Study of methane flow in caved goafs adjacent to longwall faces in Valea Jiului coal basin*, Proceedings of the 13th International Multidisciplinary Scientific Geoconference - SGEM 2013, Volume I, pp. 731-738, Albena, Bulgaria, 16-22.06. (2013).
- Moraru, R.I., Băbuț, G.B., Cioca, L.I., Ragazzi, M., *Spontaneous combustion risk analysis in subsurface environments: carbon monoxide data processing tool*, Environmental Engineering and Management Journal, Volume 16, Issue 6, pp. 1317-1322, (2017).
- Sean Thomas McKenna and Terence Richard Hull, *The fire toxicity of polyurethane foams* - Fire Science Reviews (2016).

## Accidents at work among industrial presses operators: analysis of statistics in north-western region of Romania

Nicolae Băncilă - Afrim<sup>a</sup>, Roland Iosif Moraru<sup>a\*</sup>, Lucian-Ionel Cioca<sup>b</sup>, Gabriel Bujor Băbuț<sup>a</sup>

<sup>a</sup>University of Petroșani, 20 Universității str., Petroșani 332006, Romania

<sup>b</sup>Lucian Blaga University of Sibiu, 10 Victoriei Bd, 550024, Sibiu, Romania

---

### Abstract

Based on the European approach to the "work accident" concept, this paper addresses the occupational injuries in terms of the statistical indicators reflecting this phenomenon as a relevant factor to substantiate the need for prevention and protection of risks related to industrial presses operation. An analysis of the causes of occupational accidents during operational use of industrial presses argues the need to address prevention and protection from a new perspective, taking into account the general principles of prevention as laid down by Law nr.319 / 2006 on safety and health at work.

The aim is to investigate the evolution of occupational accidents occurred in six counties from the North – Western region of Romania, between years 2005-2016 and to obtain a preliminary picture of the magnitude and prevalence of occupational injuries for subjects operating industrial presses. Findings confirm that human errors are the main underlying causes of accidents occurring at work.

**Keywords:** accident at work; statistic indicator; press operator; human error.

---

### 1. Introduction

Determining the sequence of causes and effects leading to the generation of an accident is a basic element in the equation of prevention. Therefore, how work accidents are occurring and statistic developments in the field have been extensively studied by specialists in the field (Guburan and Usel, 1998; Feyer et al, 2001, Fabiano et al., 2004; Cheng et al., 2010; Moraru et al., 2014; Moraru et al., 2013; Moraru et al., 2016).

Considering that an accident of work requires the involvement of objective and subjective causes, whose interaction generates event, over time there have been various attempts to explain accidents, differentiated by approach and the importance given to each of triggers (Moraru, 2012). Law no. 319/2006 on safety and health at work introduces the wider generic term of "event" to describe *"the accident who trained fatality or injury produced during employment or fulfillment of duties, the situation of missing person, route or traffic accident, hazardous incident, and the work-related occupational disease"* (Romanian Parliament, 2006)). "Accident at work" is defined in the same law as *"violent injury or occupational acute poisoning that occurs during employment or service duties and causes temporary disability of at least 3 days, invalidity or death"* (Romanian Government, 2006). In this context there are noticeable some significant differences between EUROSTAT definition of accident at work and the legislation in Romania, transposing Directive 89/391 / EEC. Thus, Regulation (EC) No. 349/2011 of the European Commission implementing Regulation (EC) No. 1338/2008 of the European Parliament and of the Council on Community statistics on public health and health and safety at work concerning defines the accident at work as any *"discrete occurrence in the course of a occupational activity, which leads to physical or mental injury"* (CEU, 1986), regardless of consequences and its scale, while in Romania, events that lead to an inability to work less than 3 consecutive days are not included in this category. This is one reason why the legislator felt the need to introduce the term *"event"*. Another term used in the literature is the *"hazardous incident"* that, according to Law nr.319 / 2006 means *"identifiable event, such as explosion, fire, technical*

---

\* Corresponding author. Tel.: +40 723 624 105; fax: +40 254 543 491  
E-mail address: roland\_moraru@yahoo.com.

accidents, emissions of major pollutants, resulting the failure of an activity or a work equipment and / or the inappropriate behavior of the human factor, which did not affect workers, but it would have been possible to have such consequences and / or caused or were likely to cause losses" (Romanian Parliament, 2006). This term came also from the need to expand the scope of situations in which workers must be protected in their physical and / or mental integrity. There are several ways of highlighting, in statistical terms, the situation of occupational accidents. In the literature, are used primary indicators expressed in absolute values and derived indicators expressed as relative values (Babut et al, 2011; European Union, 2010; ILO, 2012; Northwood et al, 2012; Takala et al, 2006; Wiatrowsky, 2014).

## 2. Evolution of occupational accidents primary indicators between 2006 – 2015 in Maramureș , Cluj , Bihor , Sălaj , Bistrița Năsăud and Satu Mare counties

**Primary indicators** are obtained in the primary processing of statistical data following a process of centralization of data. They have concrete content and form of expression, being measured in the natural units. For this reason, the primary indicators are also called **absolute indicators** or indicators expressed in absolute values and they represent the basis of information statistical knowledge. For statistical analysis of occupational accidents, the following primary indicators are used:

- *The total number of injured workers* - the number of affected workers for which the consequences of accidents is terminated during the reference period, whether the event occurred during the same period or in previous periods.
- *The total number of victims* - the number of persons injured (dead or with temporary disability), recorded in the reference period.
- *Number of days of temporary disability* resulting from accidents, corresponding with the *total number of injured workers*. Depending on what is intended by the statistical survey, temporary disability days lost are considering the calendar days or working days.

Often statistical studies of this kind are referring to *the average number of employee*. In determining this indicator should be considered all activities of an enterprise and the staff turnover in the reporting period. Primary indicators provide a suggestive image of the extent of the situation, but without allowing a correct curve plotting for the evolution with time of the work accident phenomenon. Indicators expressed in absolute values do not take into account developments in the labour market, the variation in the number of employees or work program, which makes irrelevant a comparison of such indicators, not reflecting the real evolution or involution of the situation. After presenting statistically the average number of employees in north-western counties of Romania in graphical expression (Figure 1), in the same format we highlight the evolution of statistical indicators of accidents at work between 2006-2015 the analyzed region, accidents at work resulting in temporary incapacity for work (Figure 2), fatal accidents (Figure 3) and disabling accidents at work (Figure 4).

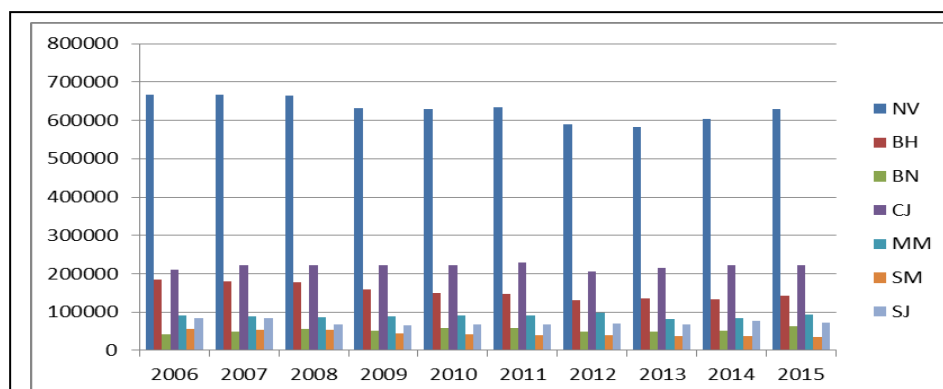


Fig.1. Average number of employees in north-western Romanian counties

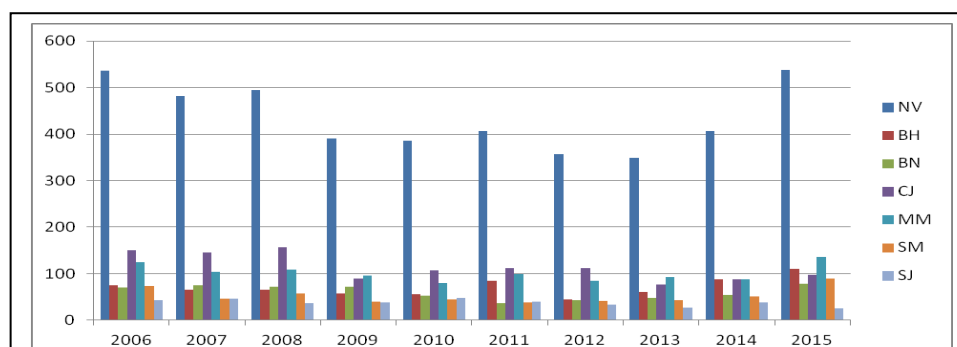


Fig. 2. Evolution of statistical indicators of accidents at work between 2006-2015 in north-western Romanian counties - accidents with temporary work incapacity

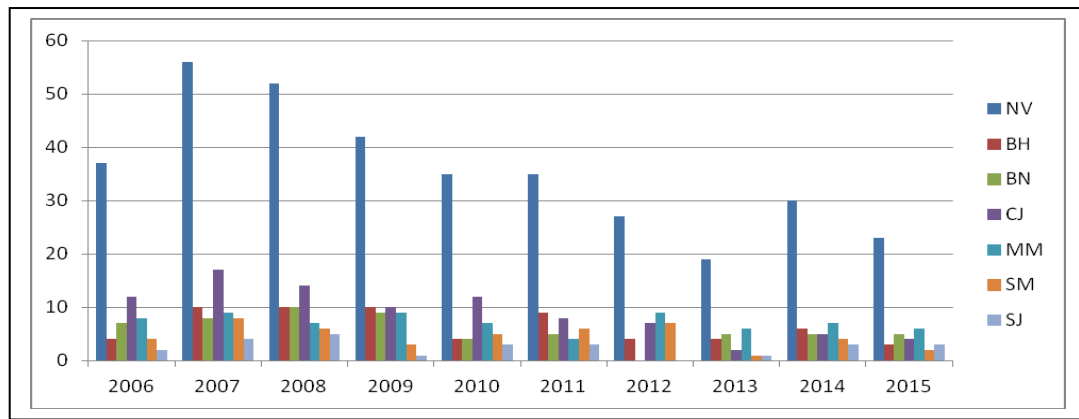


Fig 3. Evolution of statistical indicators of accidents at work between 2006-2015 in north-western Romanian counties – fatal accidents

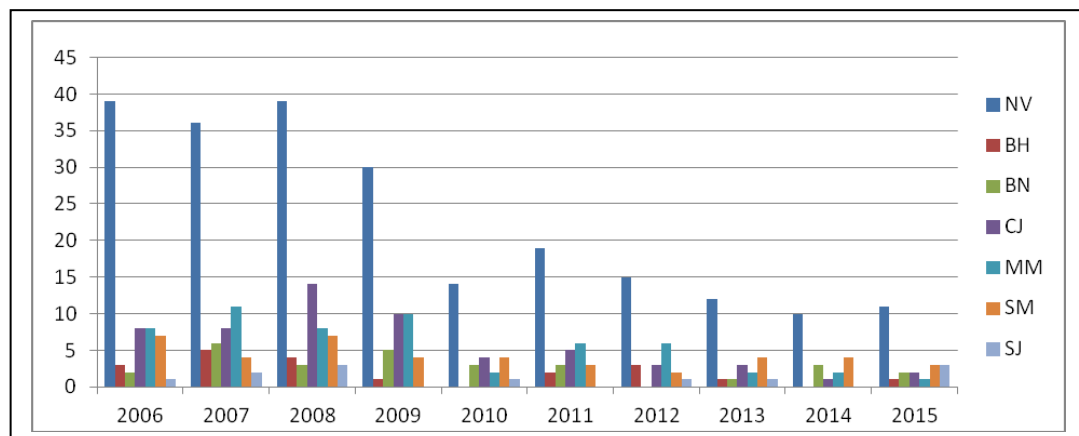


Fig. 4. Evolution of statistical indicators of accidents at work between 2006-2015 in north-western Romanian counties –disabling accidents

### 3. Evolution of occupational accidents derived indicators between 2006 – 2015 in Maramureș , Cluj , Bihor , Sălaj , Bistrița Năsăud and Satu Mare counties

*The derived indicators* are calculated as the ratio between two absolute values so that they are known as *indicators expressed in relative values*. Unlike the primary indicators the analysis of those expressed by relative values are more accurately capturing the time evolution of the occupational injury phenomenon. While reported to 1,000 workers they make the figures comparable regardless of employment market development. For statistical analysis of accidents at work the following derived indicators are used:

- **Average Duration Index** (IDM) expresses the ratio between the total duration of temporary work incapacity (ITM), and the number of injured workers with ITM in the same period, expressed in days. IDM expresses both the accident severity and the effectiveness of the medical recovery system.
- **Gravity Index** (IG) expresses the severity scale of accidents that occurred in the statistically analysed entity. It is determined by the total number of man-days of work incapacity, for 1000 workers.
- **Frequency Index** (IF) expresses the frequency of the injury in the analyzed entity, namely, how many workers per 1000 were injured.

Frequency index is calculated for a reference period. The indices of frequency, gravity and of average duration allowing to perform factorial analysis, analysis of distribution of values, etc., thus making it possible to study the common factors and deviations which may be of practical interest. It should be stressed in this context the difference between the indicators used in Romania and those used in EUROSTAT system, where the number of accidents is related to the average number of hours worked. We believe that this latest version is more suggestive and reflect more accurately the real situation.

Next we present in the same graphic expression the evolution of derived statistical indicators of accidents at work in the period 2006-2015 in counties in north-western Romania, respectively and the gravity index (IG, Figure 5), average duration index (IDM, Figure 6 ) and the frequency index (Figure 7).

As a significant related value, which can be correlated with these indexes, the figure 8 gives the total number of Temporary Work Incapacity days between 2006-2015 in the investigated north-western Romanian counties.

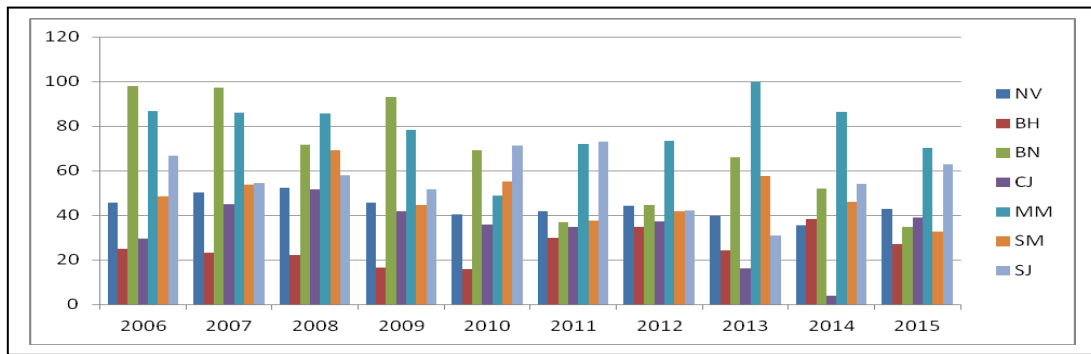


Fig. 5. Evolution of gravity index for accidents at work occurred between 2006-2015 in north-western Romanian counties

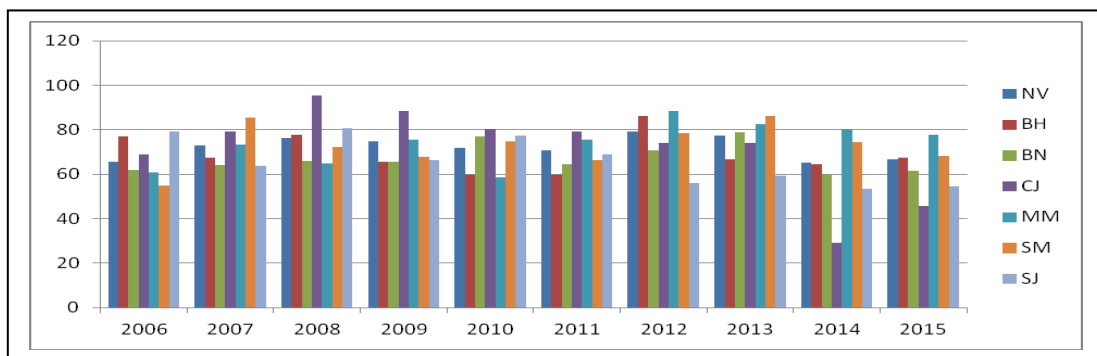


Fig. 6 . Evolution of average duration index for accidents at work occurred between 2006-2015 in north-western Romanian counties

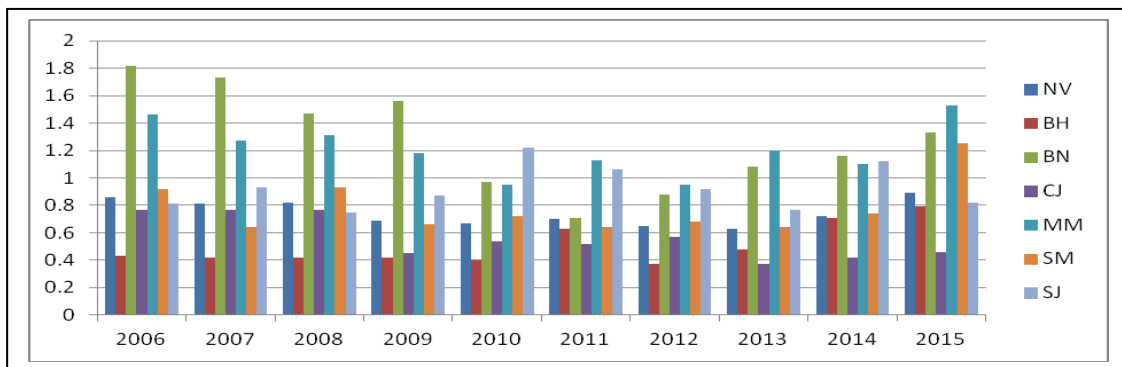


Fig. 7. Evolution of frequency index for accidents at work occurred between 2006-2015 in north-western Romanian counties

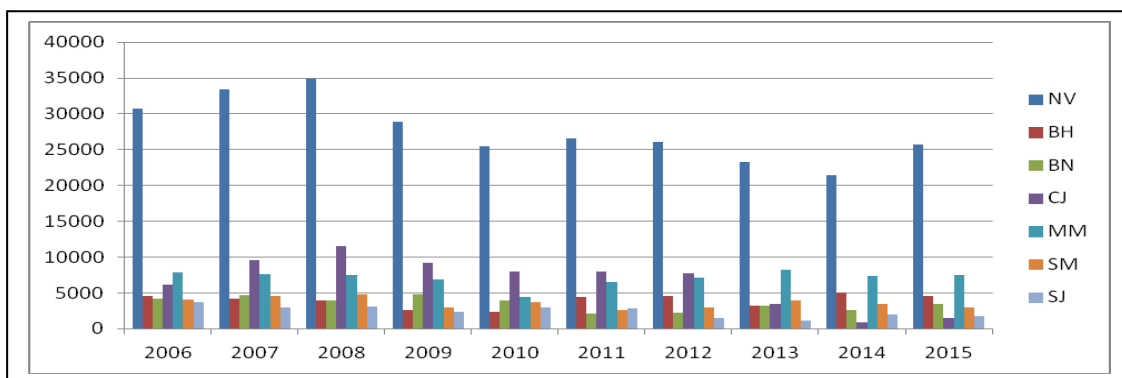


Fig. 8 . Total number of Temporary Work Incapacity days between 2006-2015 in north-western Romanian counties



#### 4. Statistical inventory of accidents at work occurred between 2005 – 2016 in Maramureș county in industrial presses operation

Study of safety and health at work must begin by knowing the general problems, the basic focus being placed on the risk factors of accidents and professional diseases that may occur in work processes and key measures to combat them. After acquiring this knowledge valid for all conditions and jobs will be addressed issues specific to certain industries. Socialization of production has generated a new situation: the beneficiary, leader, organizer and executor of work are distinct. Consequently, the first ones will be an additional source of potential danger either directly or indirectly, becoming largely responsible for exceeding the normal consumption of the labor contractor. Added to this is the ability the means and equipments which are employed in performing the working task, the work environment in which the process takes place and the workers itself, to disrupt the normal course of activity.

Automation (with its related monotony of the work and the pace imposed), the new technologies, the raw materials used, etc. may affect in different ways anatomical and functional integrity of the press operator. Table 1 is highlighting statistics of occupational accidents in the county of Maramureș in activities which are using mainly industrial machinery as presses.

Table 1. Statistics of occupational accidents in Maramureș county in activities which are using industrial presses

Branch	Year											
	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Textile, clothing, footwear industry	5	1	4	1	6	1	1	1	1	2	1	3
Wood processing industry	21	21	21	16	18	12	17	18	14	19	22	21
Paper, plastics, ceramics manufacturing	9	7	2	3	1	7	6	7	11	8	9	4
Metalurgy	9	13	9	5	5	4	4	5	3	7	6	7
Steel work	7	9	4	8	8	5	7	7	8	4	10	13
Mining	26	12	3	3	1	0	0	0	0	0	1	1
Agriculture	0	1	1	1	0	2	2	1	1	0	2	1
Forestry and logging	5	3	4	19	5	5	7	4	5	6	7	7

The figures revealed by this analysis are highlighting the need for increased prevention and protection with particular attention to the SME sector. As mentioned above, in analyzing the absolute values of work accidents should be considered the phenomenon of significant decrease in the number of workers in the national economy. Hence, again, the need for indicators that take into account the variation in the number of employees or of the overall hours worked. Out of 1082 accidents in Maramureș County during the years 2005 to 2016, 55 occurred in operating industrial presses of various types.

Figure 9 shows the synthesis of a quasi-exhaustive analysis conducted on accidents at work occurred in the period from 2005 to 2016 at the operational use of machines such as industrial presses in 28 companies / enterprises in Maramureș county.

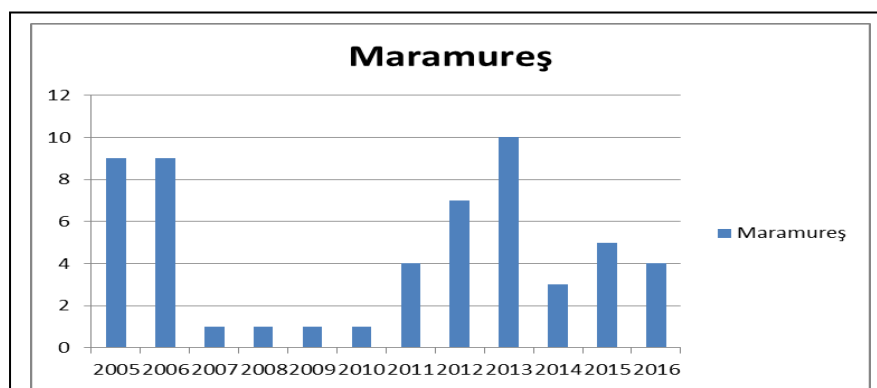


Fig. 9. Accidents at work at industrial presses in Maramureș county between anii 2005-2016

From the statistical study carried out it resulted the fact that root causes were 100% dependent on the human factor involved in the operation of industrial presses.

## 5. Conclusions

Starting from the new European approach to the concept of "accident at work" this paper has addressed the phenomenon occupational injury and disease from the perspective of the statistical indicators reflecting this phenomenon as a relevant factor to substantiate the need for prevention and protection, including those aimed at eliminating or minimizing the risks associated industrial presses operation. The analysis was based on secondary information from the Labor Territorial Inspectorates information system.

Based on a quasi-exhaustive analysis performed on accidents at work occurred during 2005-2016 in operational use of such machines as industrial presses within 28 companies / enterprises in Maramures county it was emphasized on the one hand the fact that all unwanted events in which the press operators have undergone various types injuries or health issues had as primary cause what is referred to generically in the literature as "human errors" and, on the other hand, the fact that 10 investigated companies have registered 37 from the total of the 55 accidents at work. This share of 67% is another statistical indicator of major importance and significance in highlighting certain accidental behavior patterns arising from malfunctions and latent failures of organizational nature that will determine that further studies and researches to pay a more thorough attention to the reciprocal relationship "human factor - safety management".

## References

- Băbuț, G.B., Moraru, R.I., Cioca, L.I., „Kinney methods”: useful or harmful tools in risk assessment and management process?, Proceedings of the 5th International Conference on Manufacturing Science and Educations (MSE 2011), Volume II, pp. 315-318, Sibiu, Romania, 02-05.06. (2011).
- Cheng, C., Leu, S.S., Lin, C., Fan, C., Characteristic analysis of occupational accidents at small construction enterprises. *Safety Sci.* 2010;48(6):698–707. doi: 10.1016/j.ssci.2010.02.001., (2010).
- Council of the European Union, *Council Directive 89/391/EEC of 12 June 1989 on the introduction of measures to encourage improvements in the safety and health of workers at work*, Official Journal of the European Communities, L 183/29 June 1989, Vol. 32, pp. 0001-0008, (1989).
- European Union, *Health and Safety at Work in Europe (1999–2007). A Statistical Portrait. Eurostat*. Luxembourg: Publications Office of the European Union, (2010).
- Fabiano, B., Currò, F., Pastorino, R., A study of the relationship between occupational injuries and firm size and type in the Italian industry. *Safety Science* 42(7): 587–600, (2004).
- Feyer, A.M., Williamson, A.M., Stout, N., Driscoll, T., Usher, H., Langley, J.D., Comparison of work related fatal injuries in the United States, Australia, and New Zealand: Method and overall findings. *Inj Prev.* 7:22–8, (2001).
- Gubéran, E., Usel, M., Permanent work incapacity, mortality and survival without work incapacity among occupations and social classes: a cohort study of ageing men in Geneva, *International Journal of Epidemiology*, vol. 27, no. 6, pp. 1026–1032, (1998).
- ILO (International Labour Office), *Improvement of National Reporting, Data Collection and Analysis of Occupational Accidents and Diseases*. Geneva: ILO, (2012).
- Moraru, R., *Current Trends and Future Developments in Occupational Health and Safety Risk Management*, in *Risk Management for the Future - Theory and Cases*, Dr Jan Emblemssvåg (Ed.), , InTech, DOI: 10.5772/1809, (2012).
- Moraru, R.I., Băbuț, G.B., Popescu-Stelea, M., Prerequisites for safety diagnostic and risk analysis integration in complex industrial facilities, *Quality - Access to Success*, Volume 17, Issue 151, pp. 92-99, (2016).
- Moraru, R.I., Băbuț, G.B., Popescu-Stelea, M., Approaching occupational safety and health emerging risks categories and prevention, *Quality - Access to Success*, Volume 15, Issue 139, pp. 104-108, (2014).
- Moraru, R.I., Băbuț, G.B., Cioca, L.I., *Study of methane flow in caved goafs adjacent to longwall faces in Valea Jiului coal basin*, Proceedings of the 13th International Multidisciplinary Scientific Geoconference - SGEM 2013, Volume I, pp. 731-738, Albena, Bulgaria, 16-22.06. (2013).
- Northwood, J.M., Sygnatur, E.F., Windau, J.A., Updated BLS occupational injury and illness classification system, *Monthly Labor Review* (U.S. Bureau of Labor Statistics, August), pp. 19–28, (2012).
- Romanian Government, *Government Decision no. 1425 for approval of Methodological Norms for applying Occupational Safety and Health Law no. 319/2006* (in Romanian), Official Journal of Romania, part I, no. 882/30.10.2006, Bucharest, Romania, (2006).
- Romanian Parliament, *Law no. 319 regarding occupational safety and health* (in Romanian), Official Journal of Romania, part I, no. 646/26.07.2006, Bucharest, Romania, (2006).
- Takala, J., Härmäläinen, P., Saarela, K.L., *Global estimates of occupational accidents*. *Safety Sci*; 44: 137–156, (2006).
- Unsar, S., Sut, N., General assessment of the occupational accidents that occurred in Turkey between the years 2000 and 2005. *Safety Science*;47(5):614–9. doi: 10.1016/j.ssci.2008.08.001, (2009).
- Wiatrowski, W.J., Examining the completeness of occupational injury and illness data: an update on current research, *Monthly Labor Review* (June 2014), available at [www.bls.gov/opub/mlr/2014/article/examining-the-completeness-of-occupational-injury-and-illness-data-an-update-on-current-research-1.htm](http://www.bls.gov/opub/mlr/2014/article/examining-the-completeness-of-occupational-injury-and-illness-data-an-update-on-current-research-1.htm), (2014).

## Computational study for improving the quality of safety measures for LPG filling stations

Vlad Mihai Păsculescu<sup>a\*</sup>, Emilian Ghicioi<sup>a</sup>, Marius Simion Morar<sup>a</sup>, Dragoș Păsculescu<sup>b</sup>,  
Marius Cornel Șuvar<sup>a</sup>

<sup>a</sup>National Institute for Research and Development in Mine Safety and Protection to Explosion – INSEMEX, 32-34 G-ral Vasile Milea street, Petroșani, 332047, Romania

<sup>b</sup>University of Petroșani, 20 Universității street, Petroșani, 332006, Romania

---

### Abstract

Fire and explosion risk assessment and consequence modeling for hazardous storage facilities is of great importance, taking into account the potential hazards for the local population and surrounding assets. In this case, consequence modeling aims the estimation of numerical values or the graphical representation which describe the physical outcomes of various accident scenarios involving a LPG filling station located in an urban area, with respect to their impact on people or assets. In case of LPG filling tanks may occur malfunctions, thus generating leakages which may escape into the atmosphere, may burn as jet fire or the tank may even explode and generate the fireball burning of the LPG (boiling liquid expanding vapour explosion - BLEVE). Moreover, the proximity of LPG filling stations to populated areas may magnify the potential damage. Prescriptive regulations in force govern the design, execution and exploitation of LPG filling stations. In this paper, various emergency situations which may occur in case of a LPG filling station are modeled and simulated using specialized software. Also, there are analyzed the safety measures from regulations in force concerning the location of such units in urban areas and the safety distances set in the regulations are compared to the ones generated using software tools, leading to measures proposed for limiting the effects of the studied phenomena.

**Keywords:** filling station; fire; explosion; LPG; safety distance;

---

### 1. Introduction

Leakage of pressure vessels from LPG (Liquefied Petroleum Gas) filling stations may lead to hazardous fire or explosion type events. One of the most hazardous situations is the one involved by the (BLEVE) Boiling Liquid Expanding Vapour Explosion. Once the gas is ignited, it leads to the formation of fireballs (Kamaei et al., 2016).

Taking into account the price of LPG/litre which is less than half the price/litre of regular fuel (petrol and diesel), the number of vehicles using LPG as has increased over the past years. Most LPG filling stations are located in inhabited areas, this involving the potential risk of casualties if any accident takes places. In fact, in several places of the world happened before accidents involving LPG filling stations which have resulted in human and material losses.

Even if the safety measures have been improved in time, it is practically impossible to avoid such accidents completely. Therefore, it is of high importance to assess the possible consequences of the accidents and to better understand the accidental scenarios. In this paper, there has been performed an attempt to analyse the consequences of an LPG release from the tank of a LPG filling station located in an inhabited area. T

he catastrophic failure of the pressure vessel is analysed using state-of-the art computational methods, investigating different scenarios concerning the distances around the LPG filling station which are likely to be hazardous for facilities and persons nearby (Suvar et al., 2012, and Suvar et al., 2014), taking into consideration the huge amount of energy which can be emitted in case of such accidents.

---

\* Corresponding author. Tel.: +40 765 616 288; fax: +40 254 546 277.  
E-mail address: vlad.pasculescu@insemex.ro.

## 2. Safety distances

Safety distances relate to the distance from a hazardous equipment/process (Irimie et al., 2017) representing the lowest separation which is going to mitigate the effect of an of a likely foreseeable incident and to prevent a minor incident escalating to a larger incident. Also, safety distances have to be established for providing protection from foreseeable external impact or activities outside the control of the operation ((Buica et al., 2017; Micu et al., 2017). Concerning LPG filling stations, Romanian regulations in force establish safety distances in compliance with the destination of the installation, the destination of the adjacent buildings / premises and the capacity / type of the tanks (Table 1). Taking into account the progress in terms of safety measures for decreasing risks to an as low as possible level, recent projects of such regulations tend to provide lower safety distances (Table 2) (ANRE Project, 2015; ANRGN Decision, 2006; MLPTL Normative, 1999; WLPGA Guidelines, 2008).

Table 1 Examples of relevant safety distances between the LPG filling station with over-ground tank ( $V \leq 5 \text{ cbm}$  water equivalent) and neighbouring constructions according to NP 037/1999.

No.	Type of construction	Distance to the LPG filling station [m] *
1.	Living homes:	
	- apartment houses located in residential districts	40
	- individual houses located in isolated areas	20
2.	Education buildings (kindergarten primary and secondary schools, high-schools and universities)	40
3.	Health buildings (hospitals, clinics, orphanages, retirement homes, rescue stations and other sanitary units)	40
4.	Cultural buildings (exhibitions, libraries, cinemas, theatres etc.)	40
5.	Cult constructions:	
	- places of worship	40
	- monasteries, hermitages, cemeteries	60
6.	Commercial buildings:	
	- general stores, stores for food and non-food trade	40
	- supermarkets, trade fairs, wholesale storages	50
7.	Sports buildings:	
	- sports complexes, stadiums, ice skating rinks, sports competitions buildings	60
	- training buildings, bowling alleys	40
8.	Leisure buildings: children play locations, parks	60
9.	Tourism buildings:	
	- hotels, motels and restaurants and other accommodation buildings with over 50 places capacity	40
	- hotels, motels, villas, chalets, restaurants etc. with under 50 places capacity	20
10.	Highways and international roads	30
11.	National and county roads	15
12.	Local public streets	10

\* Distance is measured from the tank vessel and/or from the tank filling point

Table 2 Examples of relevant safety distances between the LPG filling station with over-ground tank ( $V \leq 5 \text{ cbm}$  water equivalent) and neighboring constructions according to NTGPL 2015 Project

No.	Type of construction	Distance to the LPG filling station [m]	Observations
1.	Individual homes and their annexes. Sports fields. Cemeteries.	15	
2.	Residential blocks, apartment houses	20	
3.	Children play areas, Parks, Leisure areas. Civil constructions: Education, Health, Culture, Cult, Commercial, Tourism, Administrative, Sports (sport halls, sports fields with tribunes etc). Any other civil constructions.		Distance is measured from the limit of the building (base of the building, limit of the sports field/play area etc.)
		25	
4.	Highways and Express Roads	15	
5.	National and County Roads	9	Distance is measured from the edge of the road
6.	Streets and local access roads, other than the previous	7	

## 3. Considerations on mathematical modelling of hazardous events

The continuous improvement of mathematical models has led to their wide use for estimating the effects of hazardous events (Niculescu and Pasculescu, 2015, and Vlasin et al. 2016). Mathematical models developed comprise sets of equations describing events and which are able to provide the prediction of issues such as thermal radiation generated by fire type events, maximum pressure generated by explosion type events, distance and direction of thrown pieces or change in gas concentration after releases (Prodan et al., 2016).

For predicting such phenomena (Leba et al., 2014) the first step is to estimate the amount of materials involved in the incident and the rate of emission, achieved by initial condition models. Initial condition models are based on heat transfer and on fluid dynamics, requiring temperature and pressure parameters of materials. These parameters change once with the change of conditions, changing for example once with the heating of the pressure vessel.

Also, for calculating the output flow rate arising from a leak of a pressure vessel, there are required the data concerning the shape and size of the leak information which are unlikely to be available in case of accidents, therefore using simplified assumptions or standard initial conditions (Pasculescu et al., 2015a; Pasculescu et al., 2015b; Pasculescu et al., 2014).

Safety engineers and researchers have developed mathematical models which are able to describe effects of complex phenomena, such as fires, emissions or explosions, models expected to provide accurate results, but which require a wide range of data which is not always available (Babut et al., 2011; Lupu et al., 2017). After the characteristics of an accident are determined, there may be employed damage assessment models for predicting the effects on surrounding people and buildings (Cioclea et al., 2015; Magyari et al., 2015).

For such analyses, mathematical models have been implemented within state-of-the-art software tools which are commercially or open-source made available for experts in the health and safety field.

#### 4. Overview of Phast Software

There are a number of software tools which can be used for modelling consequences of chemical releases, such as Phast, Aloha or Degadis. However, for the analysis performed and presented in this paper there has been opted for using the Phast 8.1 software, taking into account that the validated mathematical models incorporated and the particular use for tank's explosion (Technical Datasheet, 2018). Phast 8.1 is a commercial software for mathematical modelling of various hazardous situations such as dispersions, fires or explosions which can be used for assessing the consequences of these scenarios so that to be able to better understand their behaviour in order to prevent possible material and human losses. Using Phast 8.1 there can be performed the following main computational simulations and modelling:

- Discharge of mixtures of pure substances or components.
- Dispersion The software includes the Uniform Dispersion Model (UDM) of DNV GL, a global scale dispersion model for: Jet, heavy and passive dispersion phases; Buoyancy; Interaction with the substrate; Gaussian pan; Drip formation and rain-out phenomenon;
- The rain-out phenomenon;
- Spreading and vaporization;
- Indoor and outdoor analysis of toxic effects in the wind direction;
- Radiation, explosions and fires: Jet Fire, Pool Fire, Fire Ball, including the Roberts (Health and Safety Executive) and TNO models, Explosions, including TNT, Multi-energy models and Baker Strehlow.

##### 4.1. Phast Multi-Component extension

For improving the modelling capability of the software, there are available several extensions and add-ons. One of the main extensions available is the Multi-Component (MC) extensions, which brings along the following main specifications and possibilities:

- It includes integrated multi-component properties system with built-in chemical database;
- It supports the most commonly used state equations, including Redlich-Kwong, Soave-Redlich-Kwong and Peng-Robinson;
- It can generate graphs of phase composition during dispersion;
- It contains a "Pool" multi-component vaporization mode.

##### 4.2. Phast 3D Explosion extension

The 3D Explosion Extension adds the advanced vapor / gas cloud modeling capability (incorporating the Baker-Strehlow-Tang and Multi-Energy models) taking into account interactions between the flammable cloud profile and the congested regions of process installations in all three dimensions (length, width, height), according to wind conditions, to characterize the explosive potential and the generated loads (eg overpressure, pulse and duration).

- Selection of technical capabilities:
- Advanced Vapor Cloud Explosion Modeling (VCE), allowing for a more detailed and realistic explosion hazard analysis.
- Multi-scenario contouring of hazards.
- Able to provide directional modeling.
- Allows a detailed analysis of a series of dangerous consequences associated with a dangerous event, taking into account various factors that influence its development (eg variation in weather conditions).
- Uses connected models so that complete analysis of an event and its associated consequences can be executed in a single integrated computation execution.

- It incorporates powerful viewing tools that allow application ranges to be applied to location maps, allowing a clearer understanding of impact areas.
- The results of the analysis can be presented in different formats (graphs, tables, comments).

## 5. Case study - LPG pressure vessel leak

For performing the consequence analysis, there has been used the case of a mono-block LPG filling station, located in an inhabited area, whose technological diagram is presented in Figure 1. In the proximity of the LPG filling station are located several types of buildings and civil facilities, namely: city road (distance from LPG filling station: 8 m); restaurant with a capacity of less than 50 persons (distance from LPG filling station: 30 m); supermarket (distance from LPG filling station: 50 m); gym (distance from LPG filling station: 63 m); highschool (distance from LPG filling station: 60 m); apartment houses (distance from LPG filling station: 101 m), presented on the map in Figure 2.

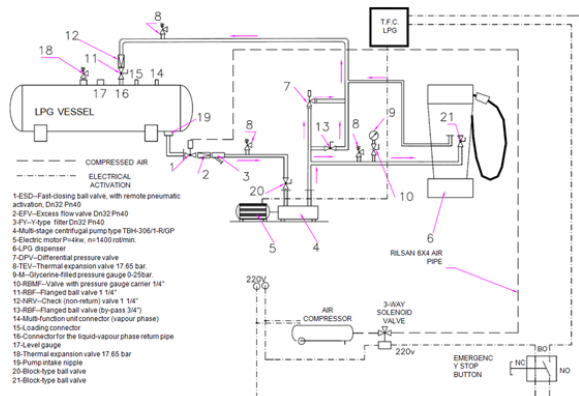


Fig.1. Technological diagram of the mono-block filling station



Fig.2. Layout of the LPG filling station and immediate surroundings

The properties of the pressure vessel and of the LPG contained along with other relevant data for performing the modeling have been set as input data for the consequence analysis. The analysis has been performed for two weather case, the meteorological information being presented in Table. 3

Table 3 Selected meteorological information

Case No.	Temperature [deg C]	Wind speed [m/s]	Wind direction	Pasquill stability
Day	25	2	NE	A very unstable – sunny, light winds
Night	10	1	NE	F stable – night with moderate clouds and light/moderate wind

After running the calculations, the software generates the data for the scenarios modeled and which can be displayed in various forms: data reports, graphs or GIS, depending on the types of interest. In the following are presented selected data concerning flash fire, fireball or explosion, resulting from the modeling of a scenario related to the catastrophic rupture of the pressure vessel and from the scenario involving a line rupture, with release in vapour phase.

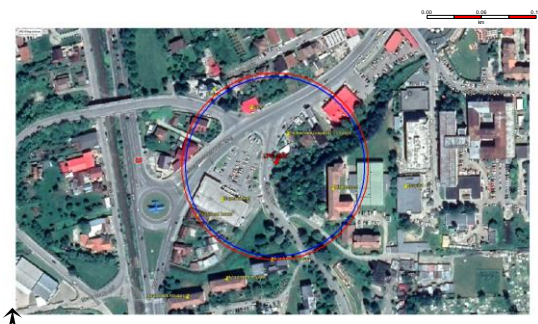


Fig. 3 Flash fire envelope, catastrophic rupture (GIS)

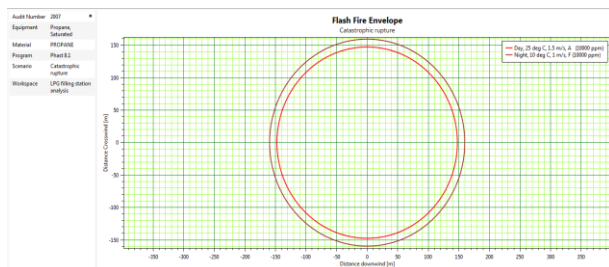


Fig. 4 Flash fire envelope, catastrophic rupture (graph)





Fig. 5. Intensity radii for fireball, 50kW/m2 (BLEVE)

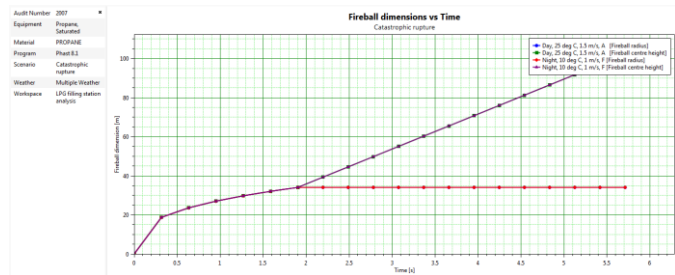


Fig. 6. Fireball dimensions vs. time



Fig. 7. Explosion worst case radii, effect zone only

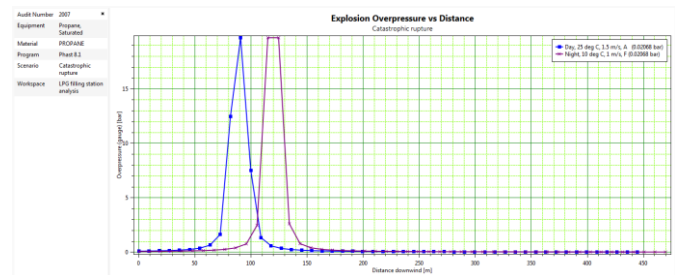


Fig. 8. Explosion overpressure vs. distance

## 6. Conclusions

Following the modelled scenarios, there can be noted that the safety distances provided in regulations are not suitable for worst case scenarios. However, even if such scenarios are unlikely to occur, it cannot be assumed that they are not possible. Therefore, using combustible materials around LPG filling stations should be limited and there have to be taken measures to that to ensure that vehicle is not going to collide with the pressure vessel and if this happens, the burning vehicle can be removed fast and safely from the area of interest so that not to head up the tank.

For determining the proper safety measures, every possible scenario has to be treated separately so that to be able to respond to each type of emergency. The use of software tools such as the one used in this paper may represent a powerful tool for risk analysis and mitigation. Results of the computational modelling of hazardous scenarios can be used for establishing area evacuation methods, safety measures for intervention teams and the type of intervention.

Since the accidents happen suddenly and are not foreseeable, it is important to maintain a buffer zone around hazardous locations. The results of the modelled scenarios can be used to identify the phenomenon causes and its effects on nearby people and equipment. On this basis, there can be implemented preventive controlling measures and also determined the proper layout and design of LPG filling stations so that to ensure the safety of personnel, civilians and surroundings.

## Acknowledgements

This paper was developed within the Nucleu-Programme, carried out with the support of Romanian Ministry of Research and Innovation, project no. PN-18-17-01-01, project title: Developing the institutional capacity for performing technical investigation of explosion/fire type events (in Romanian: Dezvoltarea capacității instituționale pentru realizarea expertizelor tehnice ale evenimentelor de tip explozie/incendiu).

Also, part of the current study is related on results gained from the work which was supported by a grant of the Romanian Ministry of Research and Innovation, CNCS/CCCDI - UEFISCDI, project number PN-III-P2-2.1-PED-2016-0089, funding contract no. 200PED/2017 within PNCDI III: "Computational method for assessing the hazardous area extent in case of gas leak explosions in confined spaces" - COMALEX (2017-2018).

## References

- ANRE Project, Project for Technical standard for the design, construction and operation of liquefied petroleum gas filling stations for motor vehicles, code NTGPL-2015, Romanian Ministry of Economy, Romanian Energy Regulatory Authority, Romania, (2015).
- ANRGN Decision, Decision for the approval of the Technical Code for Liquefied Petroleum Gas (LPG), (in Romanian), Romanian Natural Gas Regulatory Authority, Romania, (2006).
- Babut, G.B., Moraru, R.I., Cioca, L.I., "Kinney methods": useful or harmful tools in risk assessment and management process?, *5th International Conference on Manufacturing Science and Education (MSE 2011)*, Vol. II, pp. 315+, Sibiu, Romania, (2011).

- Buica, G., Antonov, A.E., Beiu, C., Pasculescu, D., Dobra, R., Occupational health and safety management in construction sector the cost of work accidents, *Quality-Access to Success*, Vol. 18, S1, pp. 35-40, (2017).
- Cioclea, D., Gaman, G.A., Gherghe, I., Radoi, F., Boanta, C., Pasculescu, V.M., Possibilities to priorly establish the structure of ventilation networks affected by underground explosions, *24th International Mining Congress and Exhibition of Turkey*, pp. 991-997, Antalya, Turkey, (2015).
- Micu, C.A., Ciubotariu-Ana P., Baci, C., Bernevig-Sava, M.A., Darabont, D.C., Bejinariu, C., Analysis of safety measures required at the urban locations of skids for supplying LPG for vehicles, *8th International Symposium on Occupational health and Safety – SESAM*, Vol. 2, Bucharest, Romania, (2017).
- Irimie, S.I., Radu, S.M., Petrilean, D.C., Andras, A., Reducing the environmental impact of a gas operated cogeneration installation, *8th International Conference on Manufacturing Science and Education (MSE 2017) - Trends in New Industrial Revolution*, Vol. 121, pp. Sibiu, Romania, (2017).
- Kamaei, M., Alizadeh, S.S.A., Keshvari, A., Kheyrkhan, Z., Moshashaei, P., Risk assessment and consequence modeling of BLEVE explosion wave phenomenon of LPG spherical tank in a refinery, *Journal of Health and Safety at Work*, Vol. 6, Issue 2, pp. 10-+, (2016).
- Leba, M., Ionica, A., Dobra, R., Pasculescu, V.M., Quality function deployment (QFD) based expert system for renewable energy structures. A wind turbine case study, *Environmental Engineering and Management Journal*, Vol. 13, No. 6, pp. 1365-1370, (2014).
- Lupu, L., Paraian, M., Paun, F.A., Jurca, A., Vata, N., Gabor, D., Implementation of new tools to calculate dispersed volume of combustible gases to achievement classification of hazardous areas, *Quality-Access to Success*, Vol. 18, S1, pp. 240-243, (2017).
- Magyari, M., Burian, S., Moldovan, L., Fotau, D., Colda, C., Variable speed drives made up of explosion proof electric motors designed for explosive atmospheres specific to oil & gas industry, *Science and Technologies in Geology, Exploration and Mining, 15th International Multidisciplinary Scientific Geoconference (SGEM)*, Vol. I, pp. 835-842, Albena, Bulgaria, (2015).
- MLPTL Normative, Normative no. NP/37 on the design, execution and exploitation of liquefied petroleum gas (LPG) filling stations for vehicles, Romania, 1999.
- Niculescu, T., Pasculescu, D., Use of numerical simulation to study capacitive loads which is connecting to an AC power source, *15th International Multidisciplinary Scientific Geoconference (SGEM), Informatics, Geoinformatics and Remote Sensing*, Vol. I, pp. 391-398, Albena, Bulgaria, (2015).
- Pasculescu, V.M., Pricop, D.G., Morar, M.S., Florea V.A., Research on the development of an expert system for selecting technical equipment intended to be used in potentially explosive atmospheres, *15th International Multidisciplinary Scientific Geoconference (SGEM), Informatics, Geoinformatics and Remote Sensing*, Vol. I, pp. 291-298, Albena, Bulgaria, (2015).
- Pasculescu, V.M., Suvar, M.C., Vlasin, N.L., Gaman, G.A., Florea, D., Computer modelling of flammable gas dispersion through leakages occurred in technological installations, *15th International Multidisciplinary Scientific Geoconference (SGEM), Informatics, Geoinformatics and Remote Sensing*, Vol. I, pp. 77-84, Albena, Bulgaria, (2015).
- Pasculescu, V.M., Radu, S.M., Ghicioi, E., Pasculescu, D., Niculescu, T., Assessing the safety level of technical equipment operating in potentially explosive atmospheres by using computer modelling, *14th International Multidisciplinary Scientific Geoconference (SGEM), Geoconference on Informatics, Geoinformatics and Remote Sensing*, Vol. I, pp. 43-50, Albena, Bulgaria, (2014).
- Prodan, M., Ghicioi, E., Lupu, C., Nalboc, I., Szollosi-Mota, A., Flammability characterisation of a petroleum derivative for increasing the safety of personnel and environmental protection, *16th International Multidisciplinary Scientific Geoconference (SGEM), Science and Technologies in Geology, Exploration and Mining*, Vol. IV, pp. 119-126, Albena, Bulgaria, (2016).
- Suvar, M.C., Lupu, C., Arad, V., Cioclea, D., Pasculescu V.M., Mija, N., Computerized simulation of mine ventilation networks for sustainable decision making process, *Environmental Engineering and Management Journal*, Vol. 13, No. 6, pp. 1445-1451, (2014).
- Suvar, M., Cioclea, D., Gherghe, I., Pasculescu, V., Advanced software for mine ventilation networks solving, *Environmental Engineering and Management Journal*, Vol. 11, No. 7, pp. 1235-1239, (2012).
- Technical Datasheet, Phast 8.1 software with MC and 3D Explosion extensions, DNV GL, (2018).
- Vlasin, N.I., Colda, C.I., Pasculescu, V.M., Pasculescu, D., Fotau, D., Turbulence modelling in computational simulation of methane explosions, *16th International Multidisciplinary Scientific Geoconference (SGEM), Science and Technologies in Geology, Exploration and Mining*, Vol. II, pp. 965-972, Albena, Bulgaria, (2016).
- WLPGA Guidelines, Guidelines for good safety practices in the LP gas industry, World LP Gas Association, (developed with the support of the United Nations Environment Programme (UNEP), France, (2008).



# Managerial strategies for optimizing ergonomics in organizations, tailored to the personality of engineers, to improve the quality of life and security of employees

Bratu Mihaela Laura<sup>a\*</sup>, Cioca Lucian-Ionel<sup>b</sup>

<sup>a</sup>“Lucian Blaga” University from Sibiu, Bulevardul Victoriei 10, Sibiu 550024, Romania

<sup>b</sup>“Lucian Blaga” University from Sibiu, Bulevardul Victoriei 10, Sibiu 550024, Romania

---

## Abstract

Ergonomics is a discipline that studies the working climate, to facilitate the individual's adaptation to the workplace. After 2000's, there has been a trend towards psychologising the work, the technology, the education. New needs of people have been defined, which have changed the workspace. There is a need for a place to relax, to rest at work, the need for socialization and activities outside the program. Thus, organizations, corporations that meet the multiple needs of employees, in order to increase the quality of the services offered, as well as to increase the quality of employees' lives as a motivational factor, appeared. Starting from the vision of the pedagogue Rudolf Steiner, the present paper proposes an inductive research, based on a questionnaire on the ergonomic modelling of the workspace of the engineers, depending on individual sensory sensitivity, in order to increase the state of well-being, the mental health of employees, as well as to improve safety at work. The paper sets out managerial strategies regarding the design, organization and finishing of a building in which engineer's work, as well as the interior design of the workspace and the relaxation space.

*Keywords:* ergonomics; engineer personality; quality of life; work safety.

---

## 1. Introduction

Ergonomics is a discipline that studies the working climate, to facilitate the individual's adaptation to the workplace. Ergonomics deals with the study of man-machine-work relationship (DEX, 2012). Etymologically, the ergonomic word comes from Greek: *ergon* means work, and *nomos* means law. Ergonomics, as discipline, is an integrated character, overcoming inter- and multidisciplinary barriers. It combines, in a harmonious unity, like a country, specific notions of engineering, psychology, sociology, economics, anthropometry, design, biology, physiology. The integration of corporate social responsibility into management structures facilitates the development of organizations (Cioca, 2014).

Business processes are becoming increasingly person-oriented, so marketing and linking top management with employees is extremely important (Cioca, 2013). The present work presents the ergonomics of production conception. The ergonomic elements to be researched in relation to the psychology of engineers will be interpreted from the point of view of the Senses Theory of the pedagogue Rudolf Steiner. The orientation of ergonomics only on visual and auditory stimulus appears to be restrictive, bearing in mind that there is research on 12 human senses.

Rudolf Steiner has identified 12 senses that complement those identified by Aristotle: the sense of life; sense of touch; the sense of movement; the sense of balance; visual sense; olfactory sense; sense of taste; the sense of heat; auditory sense; verbal sense; sense of thought; the sense of self.

In the human-work system, sensory organs receive different types of information: written instructions, other people, objects, events, and environmental factors. Following the processing of the information, the decision-makers execute the decision. In this context, it is ideal to ergonomically conceive the information sources of all analysers (of the 12 senses presented above).

\* Bratu Mihaela Laura. Tel.: 0745376880.

E-mail address: ybratulaura@gmail.com.

Workspaces are part of the IT-specific terminology and represent how to configure the control bar, buttons, and commands (Workspace, 2016). Workspace at the organization level is the configuration of the room so as to increase employee productivity. Productivity can be the direct result of settings made in the workspace, but also the indirect result of the well-being of employees.

The ultimate goal of improving workplace conditions is to increase organizational performance: productivity. To achieve this, it is very difficult to motivate employees because you are not sure that an extrinsic motivator is causing the expected psychological effect. Research has highlighted that it is much easier to increase employee well-being to improve performance within the organization. It seems that money is no longer a defining element in the attraction and retention of personnel, people want to be first and foremost happy (Ghira, 2017). In conclusion, a recipe that creates an ideal psychosocial environment cannot be defined precisely because the variation of temperamental types and group sentiment is very large.

## **2. Objectives**

The study on the psychological and behavioural profile of engineers aims at determining the characteristics of the workspace of engineers, by studying the behavioural profile, following the application of the self-evaluation questionnaire.

The purpose of the study is to optimize the human resources management methods at the organizational level and the ergonomics elements appropriate to the psychological and behavioural profile of the engineers in order to increase the employees' well-being and improve the organization's results (increase productivity).

The working hypothesis emerging from the established objectives is:

- Enhancement of the workspace by the employer increases the intellectual and physical comfort of the employees and increases the productivity of the engineers.

## **3. Methods**

The evaluation of the behavioural profile of the engineers in order to optimize the work space was done by developing a tool that directly targets the characteristics of the environment.

The sociological survey is the most widely used research method. It is a complex method, with the tools and techniques it uses. The survey is a way of knowing scientifically the opinions, attitudes, aspirations of people and being a means of influencing it. It achieves quantifiable results on human behaviours or other psychosocial studies (Cauc, 2007). The survey based on a questionnaire is a method of sociological research (Miftode, 1995).

116 questionnaires were completed by the engineers. All the people employed in a given place, who have manifested both availability and willingness to collaborate, have been chosen.

The present test, "Ergonomic organization of workspace", is non-standardized, does not have standardization samples. It is an objective test, with structured questions with a nominal scale. The measured dimension is sensory sensitivity. It consists of 18 statements, which contain 85 items.

## **4. Results**

The analysis of the workspace of the engineers is based on two main coordinates: the determination of the physical and psychological workspace, as described by the ergonomics of the organization.

Part I of the questionnaire, "Determining the Physical Work Space", follows four categories of stimulus:

### **1. Sensitivity of engineers to tactile stimulus**

The items on tactile sensitivity aim to discover the favourite texture of furniture engineers, objects in the surrounding area, and the favourite material for a service uniform.

### **2. Engineers' sensitivity to visual stimulus**

The visual stimuli analysed relate to the colour of the work room, the colour of the office, the clothing, and the sensitivity to the visual elements in the environment. It aims to be able to generalize a certain style of workspace for engineers.

### **3. Sensitivity of engineers to space stimuli**

The spatial stimuli analysed in the questionnaire are:

- Geometry of the workspace;
  - Perception of others in the workspace;
  - Workspace dimensioning;
  - Choosing relaxation spaces during the break.
- The characteristics of the environmental space that were analysed are:
- Order vs. Not necessarily order (avoiding the use of the word clutter because it has social negative connotations);
  - Predictable vs. unpredictable;
  - Symmetric vs. Asymmetric;
  - Lines, straight shapes vs. Curved lines, round shapes;
  - Fixed furniture vs. Modular furniture.

#### 4. Sensitivity of engineers to auditory stimuli

Testing sensitivity to auditory stimuli tracks the composition of the workspace with / without auditory stimuli. It identifies the preference for listening to music during work and pause, as well as the type of music listened to during leisure.

The music genres predefined in the questionnaire are: rock; classical; popular; pop; another genre.

Another item refers to the preference for changing the gender / permanent post. There are people who get bored quickly, they are always in change, they are not consistent in elections, they show some instability, they are impatient, they are always on the move and their behaviour is to change music permanently.

Part II of the questionnaire studies the physical and emotional interaction of engineers with the physical and social work environment in order to increase the well-being of employees.

Well-being is a concept that refers to the individual's perception of psychological health and quality of life, cognition and affectivity. The cognitive dimension is related to the subjective significance of mental health and life satisfaction, and the affective component includes personal affective, positive or negative affective practice (Tudorel, 2013, Corey, 2013, Warr, 2004, Moen, 2000).

A six-dimensional model of well-psychological state has been built, starting from a person's lifecycle and human developmental theories (Salami, 2011). The six dimensions are:

- self-acceptance - how satisfied individuals are with their own person;
- positive relationships with others - the ability to empathize and show compassion to others;
- autonomy - self-regulation of behaviour and independence in decision-making;
- environmental protection - ability to manage the environment, according to personal needs and purposes;
- the goal in life - the goals and personal goals that create it;
- personal development - continuous development and use of all capacities to reach the maximum potential (Salami, 2011).

According to the above presented model, at organizational level, environmental control and positive relationships with others have a direct impact on employees' well-being (Warr, 2017, Gough, 1998, Diener, 2000, Boehm, 2008). Recent research has explored the relationship between team work and productivity, a relationship based on increasing employee welfare (Maynard, 2013; Diener, 2017). The other three dimensions of the model indirectly influence employees' well-being through the interaction with the work environment.

##### 1. Analysing the interaction of employees with the working environment. Environmental control.

Employee control over the working environment, related to the improvement of the state of well-being, is analysed in the questionnaire by 7 items. The purpose of the questions is to establish the overall coordinates of the individual's interaction with the environment, to build an attractive workspace that increases the well-being of employees. The 7 questions are:

- I like to have plants in the field of view.
- As I work I like to look out of the window from time to time.
- I like the space I see on the glass to be ...
  - An open state;
  - With natural elements (trees, ponds, mountains, etc.);
  - Urban landscape (streets, buildings);
  - People;
  - It does not matter.
- When I'm on a break, sometimes I feel the need ....
  - Standing up;
  - Make a move;
  - Exit outside;
  - I like to stay inside.
- I like to work in a space with furniture ...
  - To stimulate my concentration power;
  - With classic lines;
  - Nonconformist.
- I like to work in position ...
  - Vertical;
  - Seated;
  - Laying down;
  - Comfortable and relaxed.
- In my workspace ...
  - I have photos, posters, amulets, memories from places of interest in the field of view;
  - I like to have familiar, personal items (cups, etc.).

##### 2. Analysis of employee interaction with the social environment at work. Positive relationships with others.

Increasing the well-being of employees at work is influenced by positive relationships with other employees as well as with hierarchical superiors. In this regard, the relationships with other people at the workplace were analysed using the following questions:

- I like to socialize with my colleagues on the break.

- In the break I like to dive into my thoughts and think about ...
  - Service related issues;
  - Family;
  - Friends;
  - What I'm about to do when I leave my job;
  - I dream my eyes open;
  - I do not want to think of anything.
- During the work pause I prefer to ...
  - I walk alone;
  - Walk with my colleagues;
  - Stand alone;
  - Being with colleagues;
  - Standing and interacting with others.

## **5. Discussions and conclusions - Ergonomic organization of the workspace**

In conclusion, if 10 engineers work in an office, then:

- Description of the individual features of the 10 engineers:
  - 5 engineers would be women, 5 men.
  - 4 people would wear uniform, 6 conform to the organization's clothing code.
  - One person would be dressed carelessly.
  - 2 are doing sports and wearing synthetic materials.
  - 5 would wear blue cotton, 3 cotton black, 1 blue cloth, and one white cloth.
  - 8 listen to music on headphones while working.
  - When they leave from work, 9 listen to music.
- Dimensioning of the room and location:
  - 10 engineers would work in 2 rooms. The first office includes 4 people, and the second office, 6, of which 2 would have individual spaces.
  - Each room is wide, airy. Space 1 would have 28m<sup>2</sup> and space 2 would have 42m<sup>2</sup>. The dimensioning is done according to the normative norms that each employee has a working space that varies between 2/3 m<sup>2</sup> and 15/18 m<sup>2</sup> (Puiu, 2010). An average value of 7 m<sup>2</sup> per person was chosen.
  - In each space, 3 employees face the window. In space 2, those working in separate spaces face the door. There are three women and three men seated facing the window.
  - The building perspective, if we consider it included in a circle, would be: 360° mountains, hills, field and 83° perspective on the city.
- Arrangement of the office:
  - The offices are white and the orange hall. At a forest detour, all the walls would be green. It is recommended to try painting the offices in the blue colour.
  - 7 spaces stimulate the power of concentration.
  - 7 offices / workspaces would be made of wood and 3 of modern materials (plastic combination with other structures).
  - The office / workspace would be light, cheerful.
  - 6 workspaces will be predictable, will not change often, and all IT will want to work in them. 4 spaces will be unpredictable, meaning they will often change their arrangement.
  - 6 spaces will be symmetrical, geometric, and 4 will be asymmetric (two of the asymmetric would be occupied by IT).
  - 5 spaces will have lines and straight shapes with a fixed movable. 5 spaces will have curved lines, round shapes and modular, mobile furniture.
  - 8 prefer a relaxed, comfortable position. 6 prefer to sit. 2 prefer nonconformist and comfortable furniture, which is 1 IT engineer. In conclusion, the IT specialist and one other employee are in the cushion chairs. 6 have very comfortable chairs and pillows.
  - There will be symmetrical / asymmetric 6 plants, 3 in each office. Of the 6 plants, 3 would be in the vicinity of the women's workspace.
  - 10 offices are ordered, but on 3 can sometimes see paper that is not put in place.
  - 4 have familiar objects on the desk (cups, personalized pad, personalized pens, etc.), of which at least one woman and one male.
- Their behaviour during the meal break (30 minutes to 8 hours of work):
  - 9 socializes with colleagues on the break, including the two working alone.
  - 8 go out and walk, one of whom walks alone. Four outdoor sports apparatus can be fitted out of metal and plastic, and a wooden circuit and climbing ropes can also be used, also for the women dressed in skirt.
  - 5 stands for stories.
  - 4 engineers would sit in the dining room and watch monitors with:
    - 12 minutes - music, of which 4 minutes pop, then radio;

- 3 minute - news;
  - 12 minute - news in the field;
  - 3 minute - meditation by wise men.
  - o 2 would sit for coffee.
  - o 2 would stay in the office (excluding those who are alone).
  - o 2 would go to the cigarette.
  - In pause, employees are thinking about:
    - o 5 to family (2 males and 3 females);
    - o 6 at what they have to do at home;
    - o 5 to friends.
- Increasing the well-being of employees by setting up a workspace according to individual needs:
- Change the attitude of employees towards work, colleagues and tasks;
  - Increase employee motivation;
  - Make collectivity fun;
  - Change employee attitudes - is optimistic;
  - Increases the level of energy concentration;
  - Increases employee performance;
  - Develops positive emotions in relation to work;
  - Reduces quitting and staying;
  - Decreases tensions and negative emotions.

### Limitations of research and future research directions

The only threat to this perfect mechanism of engaging employees in solving tasks is the phenomenon of hedonic adaptation, that is the habit of employees with that state and environment. For this reason, it is recommended to change the working environment to about 2 years.

The questionnaire also raises another problem: the grid is self-evaluation, so it represents people's perception of their own person.

### References

- Boehm, J., K., Lyubomirsky, S., Does happiness promote career success?. *Journal of Career Assessment*, p. 101–116, (2008).
- Cauc, I., Manu, B., Pârlea, D., *Metodologia cercetării sociologice: Metode și tehnici de cercetare*, Editura Fundației România de Măine, București, (2007).
- Cioca, L., I., Ivascu, L., Rus, S., Integrating corporate social responsibility and occupational health and safety to facilitate the development of the organizations, *Conference: 4th Review of Management and Economic Engineering International Management Conference*, Cluj Napoca, 2-7, (2014).
- Cioca, M., Ghete, A., I., Cioca, L., I., Machine Learning and Creative Methods Used to Classify Customers in a CRM Systems, *Conference: 17th International Conference on Innovative Manufacturing Engineering*, Iasi, vol. 371, 769, (2013).
- Corey, L. M., Mental Well-Being. International Contributions to the Study of Positive Mental Health, *Springer Science and Business Media Dordrecht*, (2013).
- Diener, E., Suh, E. M., *Culture and subjective well-being*. Cambridge University Press, (2000).
- Ghira, A., *Câți bani cheltuiesc companiile pentru fericirea angajaților români*, Consultat la 18.09.2017 de pe [www.economica.net](http://www.economica.net), (2017).
- Gough, I., Allister, M. J., *Well-being in developing countries. From theory to research*. Cambridge University Press, (1998).
- Institutul de Lingvistică al Academiei Române, *DEX – Dicționarul explicativ al limbii române*, Univers Enciclopedic, București, (2012).
- Maynard, M., T., Mathieu, J., E., Gilson, L., L., O'Boyle, E., H., Cigularov, K., P., *Drivers and outcomes of team psychological empowerment: A meta-analytic review and model test*, *Organizational Psychology Review*, 3, p. 101–137, (2013).
- Miftode, V., *Metodologia sociologică*, Porto – Franco, Galați, p. 245, (1995).
- Moen, P., Erickson, W. A., *The Cornell Retirement and Well-being Study: Final Report*, Cornell University, (2000).
- Rangu, Gh., Bojenescu, C., Tomescu, I., *Inițiere în ergonomie*, Editura Tehnică, București, (1984).
- Salami, O. S., Personality and psychological wellbeing of adolescents: the moderating role of Emotional intelligence. *Social behavior and personality*, Vol. 39, No. 6, pp. 785-794(10), (2011).

- Spațiu de lucru, *Wikipedia, enciclopedia liberă*. Preluat la 08:14 EET, iunie 20 2017 de la [//ro.wikipedia.org/w/index.php?title=Spa%C8%9Biu\\_de\\_lucru&oldid=10743996](http://ro.wikipedia.org/w/index.php?title=Spa%C8%9Biu_de_lucru&oldid=10743996), (2016).
- Tudorel, O., I., Macsinga, I., Vîrgă, D., Actualizarea de sine: de la starea de bine la viziunea asupra vieții. *Romanian Journal of Applied Psychology*, Vol. 15, no. 1, 20 – 26, (2013).
- Warr, P., Butcher, V., Robertson, I., Callinan, M., Older people's well-being as a function of employment, retirement, environmental characteristics and role preference. *British Journal of Psychology*, 95, p. 297-324, (2004).
- Warr, P., Self-Employment, Personal Values, and Varieties of Happiness-Unhappiness. *Journal of occupational health psychology*, (2017).

# Identification of risk scenarios on critical infrastructures of ultra high and very high voltage for the purpose of risk assessment and quality improvement of the National Power Grid

Nicolae Daniel Fiță<sup>a\*</sup>, Dragoș Păsculescu<sup>b</sup>, Roland Iosif Moraru<sup>b</sup>

<sup>a</sup>Romanian Association for Electrical Safety, Unirii street 2/3, Petrosani, Romania

<sup>b</sup>University of Petrosani, Universitatii street 20, Petrosani, Romania

---

## Abstract

The emergence of new types of risks and developments at the international level generate increasingly complex needs in the field of risk management, as well as implications for their management at national or local level. In this context, there is a need to use a common language in the field of risk management and a coherent and unique analysis process so as to be able to identify risks with a major impact at national level with international connotation but also integrated risk management. Critical Infrastructures at ultra high and very high voltage represent the most sensitive and most vulnerable areas of the National Power Grid, and for this purpose, critical infrastructures must be an indisputable priority for both system and power processors and those who seek to attack, destabilize and destroy National Power Grid (terrorist actions). The purpose of the paper is to identify potential risk scenarios for critical infrastructures within National Power Grid for the purpose of assessing risks and improving National Power Grid quality.

*Keywords:* risks scenarios/assessment; critical infrastructures; national power grid; quality.

---

## 1. Critical infrastructure risk assessment methodology and integrating sectorial risk assessments

### 1.1. Purpose and objectives of the methodology

Purpose: to provide a common framework for analysis of sectorial risk assessments, to provide information about the types of risks present on the territory of Romania. This methodology is applicable to all types of sectorial risks present in Romania (Cioca et al., 2010, and Web-reference, 2016).

Objectives:

- formulating unique definitions of key terms used in national risk assessment;
- developing scenarios by identifying and building them;
- prioritization and selection of scenarios that will later be included in sectorial risk assessments;
- identifying major national risks and assessing intervention capabilities that can influence the risk of scenarios; in the recommendation phase, analyzes are carried out and the resources to be supplemented are identified; cost-benefit analyzes are carried out to determine whether investments will be made to increase intervention capacity or prevent measures.

### 1.2. Types of risk identified in Romania

Natural hazards:

- dangerous meteorological phenomena (storms, floods, tornadoes, drought, frost); forest fires; avalanches; destructive phenomena of geological origin (landslides, earthquakes).

Technological risks:

---

\* Corresponding author. Tel.: +40-731-063-310.  
E-mail address: daniel@electrosecuritate.ro.

- accidents; failure; explosions and fires (industry, transport and storage of dangerous goods, transport, nuclear); water pollution; construction collapses, installations or fittings; the failure of public utilities; falling objects from the atmosphere or from the cosmos; unexploded ammunition.

Biological risks: epidemics; epizootic / zoonoses.

### 1.3. Probability and impact assessment for selected scenarios

The scenarios are framed on the Probability scale - probability calculation results in identifying the possibility of a disaster within a predefined time horizon (Pasculescu et al., 2017a, and Pasculescu et al., 2017b), considering available information.

Table 1. Probability scale

Probability scale	Time interval
1 – Low	category 1 - events that can occur once every 1000 years or more
2 – Low-Medium	category 2 - events that may occur between 100 and 1000 years
3 – Medium	category 3 - events that may occur between 10 and 100 years
4 – Medium-High	category 4 - events that may occur between 1 and 10 years
5 – High	category 5 - events that may occur several times a year

Assessment of the impact of selected scenarios - at this stage, the impact of those scenarios obtained following the application of the prioritization criteria is assessed. Impact types are defined specifically by Impact Criteria (C).

Table 2. Impact types, criteria and impact indicators

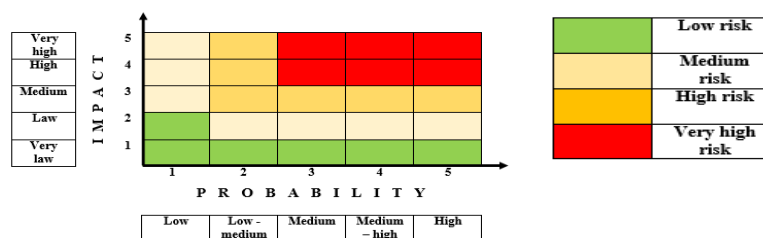
TYPE OF IMPACT	IMPACT CRITERION	IMPACT INDICATORS
T1. Impact on the population	C1.1. Deaths	Number of people
	C1.2. Wounded (injureds)	Number of medical records
	C1.3. Evacuate	Number of persons x number of days T1
	C1.4. People without access to basic services	Number of individual entries in shelters x number of days
T2. Economic and Environmental Impact	C2.1. Material and financial losses	Amount in euro and percentage of GDP (gross domestic product)
	C2.2. Environmental impact	IM (units) = affected area km <sup>2</sup> (scaled in % by reference to the protected area) x number of species x number restoration years
T3. Social and psychological impact	C3.1. Interruption of everyday life	Units (number people without access x number services to which they have no access x number of days without access)
	C3.2. Psychological impact at the society level	Index of psychological impact on society (IP)

### 1.4. Risk calculation

For the risk assessment proposed in this methodology (Pasculescu et al., 2015), the risk is mathematically expressed according to the following formula:

$$\text{Risk} = \text{Impact} \times \text{The probability of occurrence of the event}$$

Table 3. Scenario placement on the risk matrix



## 2. Identification of risk scenarios on critical infrastructures from the national power grid

### 2.1. The real functioning of the Romanian National Power Grid

In Romania, the responsibility for the safety and security of the National Power Grid operation lies with the Company TRANSELECTRICA (Web-reference, 2016), being subordinated to the Ministry of Economy, which is subordinated to the Government of Romania.



The National Power Grid (Valciu et al., 2009) is interconnected to ENTSO-E, which is the European transport and system of the European Union (Hungary, Bulgaria, North Ukraine) and the power grid of Serbia, the Republic of Moldova and South Ukraine.

TRANSELECTRICA responsibilities:

- *power carrier:*
  - operation of the power transmission network;
  - maintenance of transmission network infrastructure;
  - development of transmission network infrastructure.
- ✓ on: 81 power substations and 8834,5 km. overhead lines;
- ✓ through 8 power transmission branches and 5 subsidiaries (Opcom, Smart, Formenerg, Teletrans, Icemenerg).
- *system operator:*
  - operational management of National Power Grid;
- ✓ with: EMS / SCADA dispatching infrastructure;
- ✓ by: 1 national dispatcher - ND and 5 territorial dispatchers - TD.
- *operator on the electricity market:*
  - electricity exchanges between Romania and the European Union;
  - electricity exchanges between Romania, Serbia, Ukraine and the Republic of Moldova.

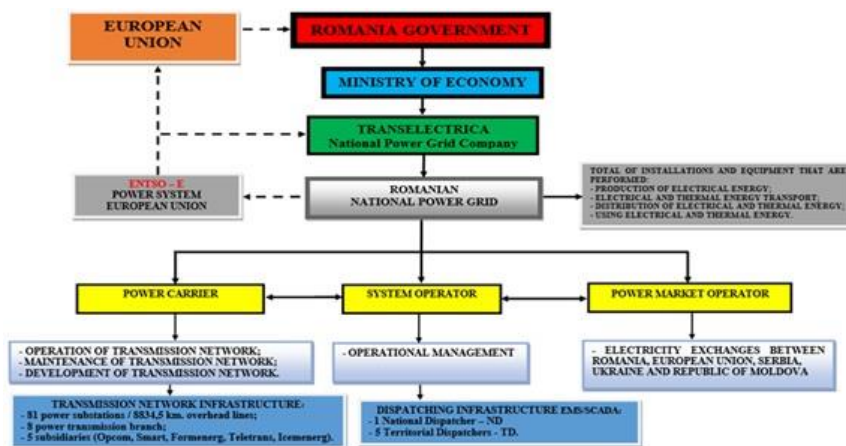


Fig. 1. The real functioning of the Romanian National Power Grid

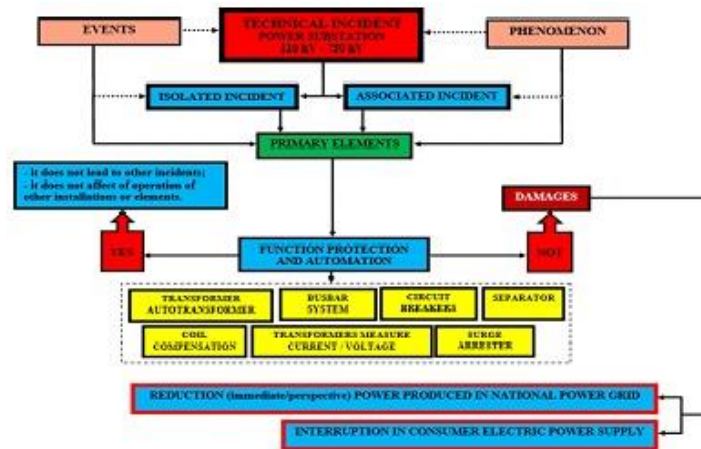
## 2.2. Identification and description of all critical infrastructures with international connection from National Power Grid

CRITICAL INFRASTRUCTURES WITH INTERNATIONAL CONNECTION FROM THE NATIONAL POWER GRID							
POWER SUBSTATION 400/220 kV ROSIORI	POWER SUBSTATION 400 kV NADAB	POWER SUBSTATION 400/220 kV ARAD	POWER SUBSTATION 400 - 220 kV RESITA	POWER SUBSTATION 400/220 kV IRON GATES	POWER SUBSTATION 400 kV TANTARENI	POWER SUBSTATION 750/400 kV ISACCEA	POWER SUBSTATION 400 kV SUCEAVA
Geographical place: - Rosiori village; - Satu Mare county.	Geographical place: - Nadab village; - Arad county.	Geographical place: - Arad village; - Arad county.	Geographical place: - Resita city; - Caraș Severin county.	Geographical place: - Iron Gates village; - Mehedinți county.	Geographical place: - Tântăreni village; - Gorj county.	Geographical place: - Isaccea district; - Tulcea county.	Geographical place: - Suceava district; - Suceava county.
Technical description: - OHL 400 kV Rosiori - Mukacevo (Ukraine) - connexion to ENTSO-E (European power grid) - OHL 400 kV Rosiori - Oradea South - OHL 400 kV Rosiori - Găldiș (injection from Thermal PowerPlant Iernut) - OHL 220 kV Rosiori - Veti - OHL 220 kV Rosiori - Baia Mare (double circuit)	Technical description: - OHL 400 kV Nadab - Bekecsaba (Hungary) - connexion to ENTSO-E (European power grid) - OHL 400 kV Nadab - Arad - OHL 400 kV Nadab - Oradea (under construction) - vulnerability, closure of the 400 kV ring in the northwest - OHL 220 kV Nadab - Timisoara (double circuit) - vulnerability 220 kV → 400 kV, closure of the 400 kV ring in the northwest	Technical description: - OHL 400 kV Arad - Sanderfaba (Hungary) - connexion to ENTSO-E (European power grid) - OHL 400 kV Arad - Mintia (injection from Thermal PowerPlant Mintia) - OHL 400 kV Arad - Nadab - OHL 220 kV Arad - Timisoara (double circuit) - vulnerability 220 kV → 400 kV, closure of the 400 kV ring in the northwest	Technical description: - OHL 400 kV Resita - Pancovo (Serbia) - double circuit - connexion to Serbia - OHL 220 kV Resita - Iron Gates 1 (double circuit) (injection from Hydro Power Plant Iron Gates 1) - vulnerability 220 kV → 400 kV, closure of the 400 kV ring in the southwest - OHL 220 kV Resita - Turisara - double circuit - vulnerability 220 kV → 400 kV, closure of the 400 kV ring in the southwest - OHL 220 kV Resita - Iaz (double circuit)	Technical description: - OHL 400 kV Iron Gates 1 - Djerdap 1 (Serbia) - connexion to Serbia - OHL 400 kV Iron Gates 1 - Urechești (injection from Thermal PowerPlant Rovinari) - OHL 400 kV Iron Gates 1 - Slatina - OHL 220 kV Iron Gates 1 - Resita (double circuit) - vulnerability 220 kV → 400 kV, closure of the 400 kV ring in the southwest - OHL 220 kV Iron Gates 1 - Cetate - OHL 220 kV Iron Gates 1 - Calafat - OHL 220 kV Iron Gates 1 - Turis Severin	Technical description: - OHL 400 kV Tântăreni - Kouloduy (Bulgaria) - double circuit - connexion to ENTSO-E (European power grid) - OHL 400 kV Tântăreni - Turceni (injection from Thermal PowerPlant Turceni) - double circuit - OHL 400 kV Tântăreni - Slatina - OHL 400 kV Tântăreni - Sibiu - OHL 400 kV Tântăreni - Urechești (injection from Thermal PowerPlant Rovinari and Hydro PowerPlant Iron Gates 1) - OHL 400 kV Tântăreni - Bradu	Technical description: - OHL 750 kV Isaccea - Pivdennoukrainska NPP (South Ukraine) - connexion to South Ukraine - OHL 400 kV Isaccea - Valciceni (Republic of Moldova) - connexion to Republic of Moldova - OHL 400 kV Isaccea - Rahman - Dondruja (Bulgaria) - connexion to ENTSO-E (European power grid) - OHL 400 kV Isaccea - Stupina - Varna (Bulgaria) - gauge 750 kV - connexion to ENTSO-E (European power grid) - OHL 400 kV Isaccea - Salted Lake (injection from Thermo PowerPlant Braila) - OHL 400 kV Isaccea - Smardan (double circuit) - OHL 400 kV Isaccea - Tulcea West	Technical description: - OHL 400 kV Suceava - Roman - OHL 400 kV Găldiș - Suceava (under construction) - vulnerability, closure of the 400 kV ring in the northeast - OHL 400 kV Suceava - Bilip (Republic of Moldova) (under construction) - vulnerability (lack interconnection to 400 kV from zone northeast) with Republic of Moldova
<div> <div>Connexion to ENTSO-E or other neighboring power system</div> <div>Injection of electrical energy from power stations</div> <div>Vulnerabilities (lack interconexion, non-closing ring 400 kV)</div> </div>							

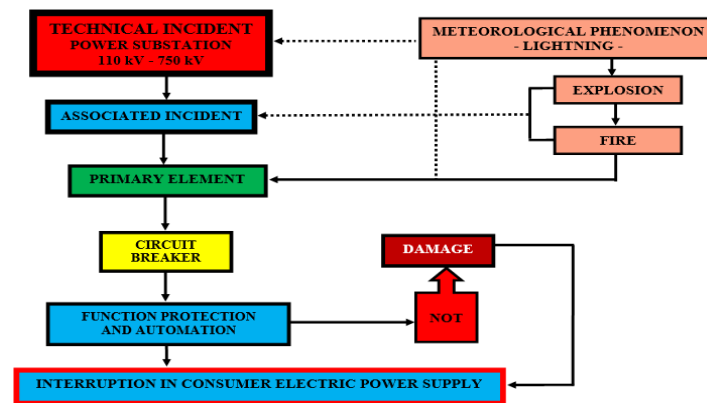
### 2.3. Identification of possible risk scenarios with effects of instability of National Power Grid

Technical Incident - 110 kV - 750 kV power substation

Timing of phenomena and events in case of a Technical Incident - 110 kV - 750 kV power substations

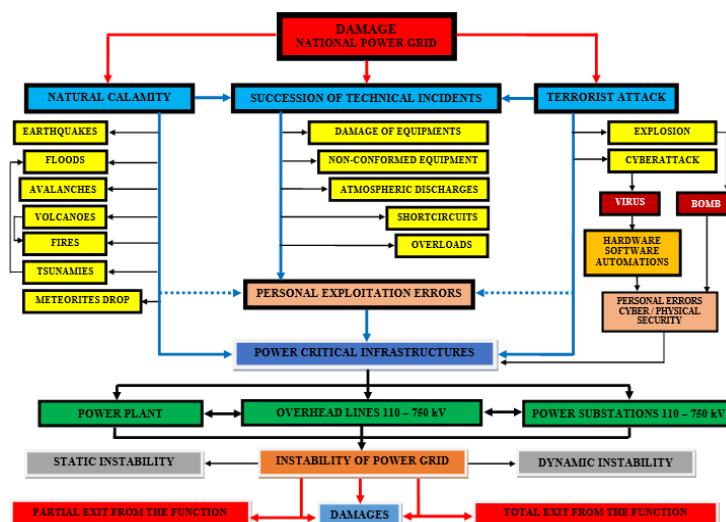


Risk scenario 1: Technical Incident: Lightning → Explosion → Fire → Interruption in Electricity Consumption of Consumers

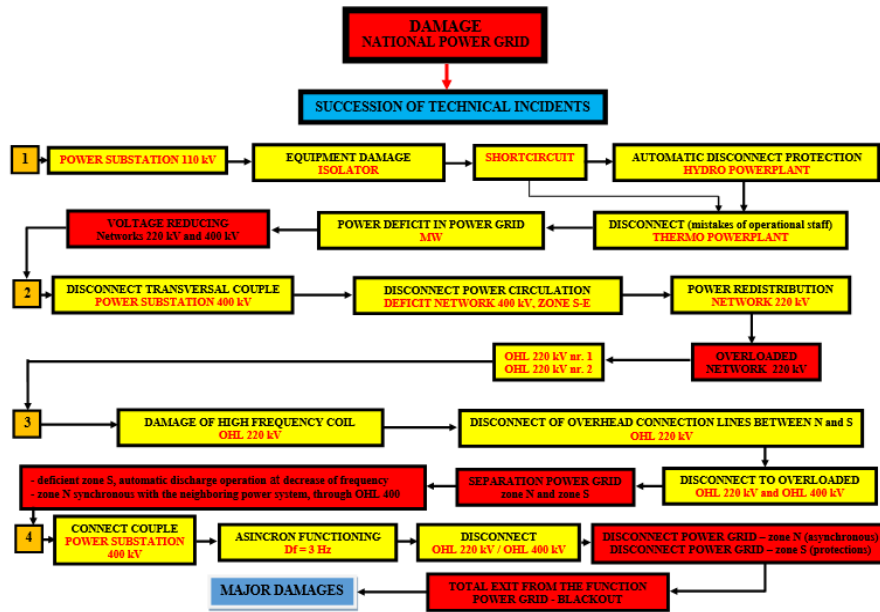


Damage – National Power Grid

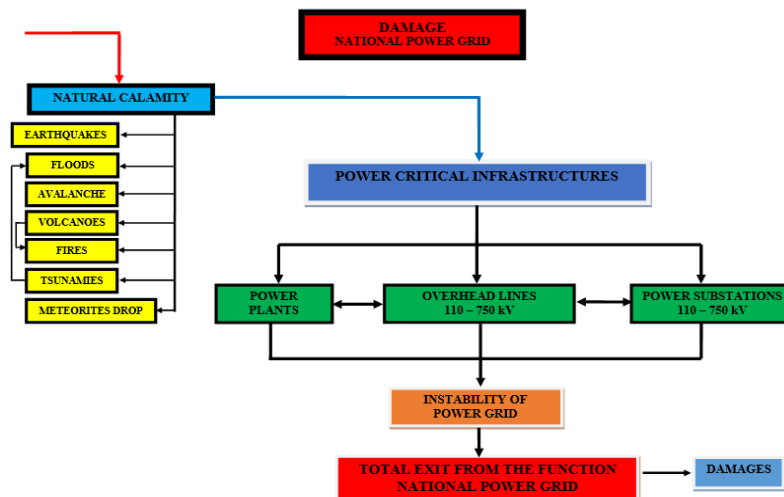
Timing of phenomena and events in case of damage – National Power Grid



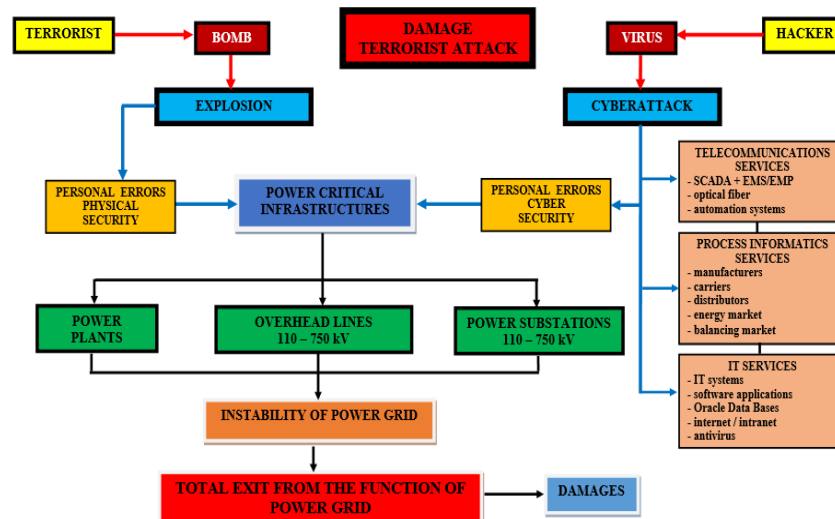
Risk scenario 2: Damage: Technical Incident Sequence - Full Output of the National Power Grid (black-out)



Risk scenario 3: Damage: Natural Calamity - Total Output of the National Power Grid (black-out)



Risk scenario 4: Damage: Terrorist Attack - Total Output of the National Power Grid (black-out)



### 3. Conclusions

The following risk scenarios for the critical infrastructures of ultra high and very high voltage from National Power Grid have been identified:

Technical Incident - 110 kV - 750 kV power substation:

- Risk scenario 1 - Technical Incident: Lightning → Explosion → Fire → Interruption in Electricity Consumption of Consumers.

Damages – National Power Grid:

- Risk scenario 2 - Damage: Technical Incident Sequence - Full Output of the National Power Grid (black-out);
- Risk scenario 3 - Damage: Natural Calamity - Total Output of the National Power Grid (black-out);
- Risk scenario 4 - Damage: Terrorist Attack - Total Output of the National Power Grid (black-out).

Once the risk scenarios have been identified, the risks associated with each scenario can be assessed.

### References

- Cioca, L. I., Moraru, R. I., Băbuț, G. B., Occupational Risk Assessment: A Framework for Understanding and Practical Guiding the Process in Romania, The International Conference on Risk management, assessment and mitigation (RIMA '10), pp. 56-61, 20-22, Bucharest, Romania, April, (2010).
- Law 18/2011 for the approval of Government Emergency Ordinance 98/2010 - The identification, designation and protection of critical infrastructures.
- Pasulescu, V.M., Pricop, D.G., Morar, M.S., Florea V.A., Research on the development of an expert system for selecting technical equipment intended to be used in potentially explosive atmospheres, *15th International Multidisciplinary Scientific Geoconference (SGEM), Informatics, Geoinformatics and Remote Sensing*, Vol. I, pp. 291-298, Albena, Bulgaria, (2015).
- Pasulescu, V.M., Vlasin, N.I., Florea, D., Suvar, M.C., Improving the quality of the process for selecting electrical equipment intended to be used in potentially explosive atmospheres, *Quality-Access To Success*, Vol. 18, S1, pp. 97-102, (2017)
- Pasulescu, V.M., Vlasin, N.I., Suvar, M.C., Lupu, C., Decision support system for managing electrical equipment used in hazardous atmospheres, *Environmental Engineering and Management Journal*, Vol. 16, Issue 6, pp. 1323-1330, (2017).
- Valciu, A., Chiuță, I., Anghel, E., Management of critical infrastructure power systems, București, Publisher Electra, (2009).
- Web-reference, [www.transelectrica.ro](http://www.transelectrica.ro), (2016).

# Computational study on the quality of the suppression effect of sprinklers on building fires spread and interaction with smoke layers

Marius Cornel Șuvar<sup>a\*</sup>, Emilian Ghiciei<sup>a</sup>, Laurențiu Munteanu<sup>a</sup>, Vlad Mihai Păsculescu<sup>a</sup>,  
Gheorghe Daniel Florea<sup>a</sup>, Niculina Sonia Șuvar<sup>a</sup>, Aurelian Nicola<sup>b</sup>

<sup>a</sup>National Institute for Research and Development in Mine Safety and Protection to Explosion INSEMEX Petroșani, 32-34 Gen. V. Milea, 332047, Petroșani, Romania

<sup>b</sup>University of Petroșani, Universității Street, No.20, Petroșani, Romania

---

## Abstract

Worldwide, fires are always a topical issue, being events with a high probability of production, followed by significant material and sometimes, human losses. Statistics show a slightly decreasing trend in the number of fires reported in recent years, respectively by victims, reflecting a growing focus on fire safety, through national regulations and legislations.

Sprinkler fire extinguishing systems fall under the category of protection and fire active control systems. They are fire extinguishers that use dispersed water in the form of droplets as extinguishing agent, dispersion made with specific armatures called sprinklers. These systems can limit or stop the development of the fire, especially in the initial phase, by inhibiting the pyrolysis of combustible materials and slowing down the process of heat transfer. In addition, sprinklers can play an important role in reducing the temperature of gaseous effluents and in changing the parameters that characterize the smoke layer (height, stability of the stratified smoke layer, etc.), thus influencing the safe evacuation capacity of the occupants.

Through the computer simulations performed in the Pyrosim application, using the FDS model, the paper aims to analyze the interaction of fire sprinkler systems, both with fire and the layer of hot gases and smoke.

Keywords: fire simulation, sprinkler systems, FDS, safety evacuation

---

## 1. Introduction

Water has favorable physical properties for fire suppression. Its high heat capacity and high latent heat of vaporization can absorb a significant quantity of heat from flames and fuels. Its property to expand considerably when it evaporates to steam conducts to the dilution of the surrounding oxygen and fuel vapors. The effectiveness of water in fire suppression is increased even more with the formation of fine droplets, due to the significant increase in the surface area of water what is available for heat absorption and evaporation (Friedman, 1997).

The fixed fire extinguishing systems use water for sprinklers and water mist equipment. The differences between the two methods mainly consist in the flow rate, the size of water droplets and the droplet size distribution.

The provision of a fire suppression system such as a sprinkler system in a building can considerably improve the life safety and property protection performance of the building. Fire sprinkler systems have revolutionized fire safety by automatically putting out fires in the room of origin and preventing fires from spreading or re-igniting. The amount of time this process requires depends on the type of fire sprinkler system. The design, installation and maintenance of fire suppression systems are regulated nationally and globally, through a series of codes of good practice, standards and regulations. These standards are based on requirements formulated by reputable organizations such as: International Code Council, the National Fire Protection Agency (NFPA), U.S. Fire Administration (USFA), etc.

Fire extinguishing systems are especially used in buildings with large areas to protect: warehouses, shopping centers, office spaces, hotels and hospitals, etc.

---

\* Corresponding author. Tel.: +4-0254-541-621; fax: +4-0254-546-277.

E-mail address: marius.suvar@insemex.ro.

The system is automatically switched on when a temperature threshold (typically ranging from 57 to 74° C) is exceeded, when the sprinkler vial breaks and the water starts to spill. Only those sprinkler heads open at which the temperature has exceeded the trigger threshold and their operation reduces the damages caused by the fire.

Overall, the sprinkler fire extinguishing system (Fig. 1) is a heat-activated automatic system. When the thermal fuse (set at about 30° C above the normal ambient temperature) reaches the activation temperature, the sprinkler head opens automatically, causing the pressure in the distribution and supply pipes to drop, then opening of the activation valve and commissioning of the sprinkler from the fire extinguishing system. After the sprinkler is opened, the water is discharged as drops. Only those sprinkler heads that are above or near the source of the fire are opened, namely those whose operation is required for the fire-fighting operation.



Fig. 1. Fire extinguishing system with sprinklers

Because fire sprinkler systems protect a variety of buildings and property, many different types have been developed over the years. These include wet, dry, deluge, pre-action and foam. Each has its own unique set of characteristics that protect the specific building and property for which it was installed.

The water-water sprinkler (wet sprinkler) system is the simplest and most used sprinkler system, especially in commercial-purpose buildings. The distribution network is filled with pressurized water, up to the sprinkler heads. When a sprinkler head is activated, the pressure inside the pipes is instantly released, providing a shorter response time than any other type of extinguishing system. This system can generally be installed in any place that is not exposed to the risk of frost.

In the case of water-air (dry) sprinkler systems, the distribution network is filled with compressed air or nitrogen. When the extinguishing head is activated, a valve releases the compressed air through the sprinkler head. After removing the air in the pipes, the pressure inside them changes, activating the ACS control and signaling station (mounted in a heated area) to pump water into the network. This mode of operation leads to a higher reaction time (delay of up to 1 minute). The accelerator guarantees fast evacuation of pressurized air or nitrogen and rapid replacement of them with water. This type of system is installed in spaces where the temperature can fall below the freezing point: loading ramps, warehouses without heating systems, etc.

Pre-action suppression systems are extinguishing systems where the sprinkler network is dry and where the control valve is connected to a fire detection system. At the time of the fire alarm, the water fills the distribution network but is not sprayed by the extinguishing heads, unless the temperature exceeds the vial break limit. These extinguishing systems can be either single interlock or double interlock; in case of the second category, the water penetration into the pipeline is subject to multiple factors: fire alarm from a smoke or temperature detector, as well as the automatic action of a sprinkler head. These systems have the advantage of ensuring a high level of protection against accidental spills, in rooms where water can cause serious damage: bookstores, archives, etc.

## 2. Sprinkler system simulation in FDS

### 2.1. Water spray dynamics

Water droplets, like fuel droplets, flow tracers and other objects that cannot be described through the numerical mesh, are treated in FDS as Lagrangian particles. These particles can be initialized to a part of the computational domain at the beginning of a calculation, or they can be introduced to the flow field from vent surfaces.

A discharge nozzle or a sprinkler is treated in FDS as a point device, namely a device located at a single point inside the computational domain, having a set of properties. For a sprinkler or a discharge nozzle, this point is the virtual origin of all particle trajectories. In practice, droplets are introduced into the flow field at a spherical surface surrounding the point device and having user-defined radius (Vaari et al., 2012).

When setting up a simulation, the user must specify the properties of the sprinkler or discharge nozzle point device, such the water spray dynamics is correctly reproduced. The sprinkler properties that must be specified are:

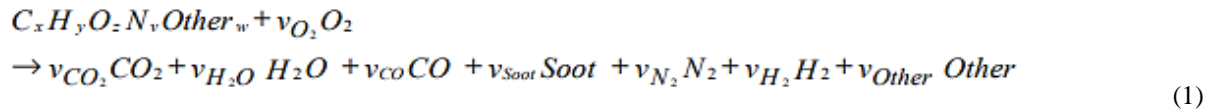
- Sprinkler name;
- Spray model: defines the particle type (water, fuel or custom type), the flow rate and the jet stream shape;



- Dry Pipe (for a dry pipe sprinkler system). The dry pipe may be created and edited at this point;
- Activator: By default, the sprinkler is activated by a temperature link, with a response time index. These properties can be selected from the menu between the already defined types (Commercial, Industrial, Residential or Storage Link, or can be edited in terms of activation temperature and response time index.
- Location of the sprinkler, as geometric coordinates;
- Orientation, meaning the components of the direction vector;
- Rotation, in the case when we need to rotate the spray pattern circumferentially.

Nozzles are very much like sprinklers, only they do not activate based on the standard response time index model. The nozzles are activated using custom control logic (McGrattan et al., 2018).

FDS models use a mixture fraction model to simulate the combustion of fuel. Simplified, the mixture fraction model assumes a reaction of the following form:



When the mixture fraction is between the lower and upper fuel specific flammability limit, the combustion will take place regardless of if an ignition source is present or not. This will increase the generated heat from the combustion and, as a result, also increasing the temperatures.

After the activation of the first sprinkler head, the water will discharge, cooling the smoke layer and cause turbulence in the enclosure. In the same time, the discharged water will control the fire growth to some extent.

FDS simulations use a number of source terms, necessary to define the problem. A user defined heat release rate (HRR) is one important source term. The extinguishing coefficient is another user defined term, defining the value with which the HRR can be reduced under the effect of the sprinkler water discharge. This coefficient must be determined empirically.

The fire can be specified as a solid fuel that does not burn at a user specified rate, where the physical properties of the burning object defines the mass burning and hence the output HRR. In this case, the sprinkler water discharge model in FDS would be able to extinguish the fire by completely halting the pyrolysis mechanism. Regardless of which burning method the user decides to choose, the sprinkler discharge simulation in FDS will cool the smoke layer by heat transfer from the hot gases to the water droplets (Carlsson, 2013).

### 3. Results and discussions

As mentioned above, the purpose of the study was to assess the capacity of the FDS to simulate the influence and the quality of a water suppression system, in the case of a virtual fire scenario. In this respect, the following aspects were followed:

- the water jet's ability to lower the temperature in the studied room, to below the critical threshold, so that the process of evacuating the potential victims to be carried out safely;
- the interaction between the discharged water droplets and the smoke and gaseous effluents layer, produced by the combustion of flammable materials;
- the system capacity to suppress the fire or to limit its evolution, for the studied scenario.

In order to analyse the efficiency of methods for optimizing the calculation time using FDS specific techniques, there have been performed several computer simulations of a fire occurring in an extremely common confined space, namely an office room (Şuvar et al., 2015).

The office compartment which is subject to this study is of rectangular shape 5x4x3m (L x W x h), according to Fig. 2. On one side there is located a door (1 m width and 2 m height), and on the opposite side a window. The furniture in the room consists of a closet with horizontal shelves, located near an office desk on which is located a portable computer. On the shelves of the closet are located several boxes with paper, specific for the work environment in the office. On the wall opposite to the closet is located another closet with doors. Office furniture (office desk, chair, closets) is made of wood (agglomerated wood - PAL). In the simulated scenario, the window is considered closed and the door is open, in order to observe the migration of hot gases and smoke on the corridor and the influence of fresh air on the combustion mechanism.

The ignition source is represented by a power supply socket, located on the wall, behind the shelves, at a 0.3 m height. The source initiates the burning of the first paper box from nearby, in a time frame which represents the sum of the pyrolysis time of the solid and the time of gaseous phase induction. From this phase, the fire increases in intensity due to the step by step combustion of flammable materials from the analysed space. In this phase, the temperature acceleration is typical.

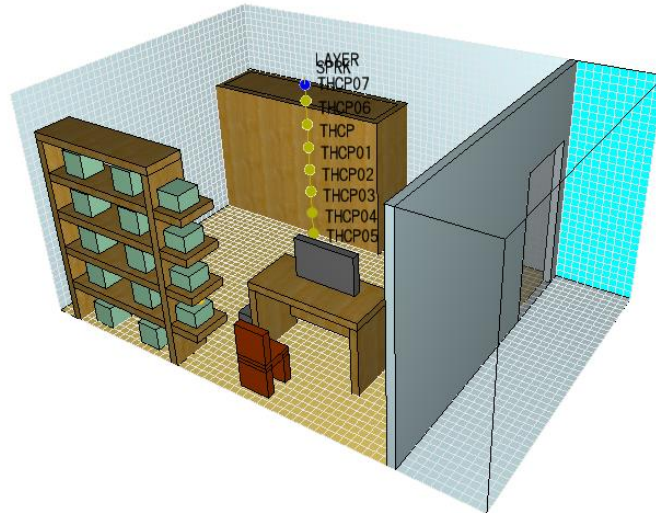


Fig. 2. Office room geometry used for FDS simulation

The flammable materials from the analyzed model are: wood (agglomerated wood, in furniture composition), PVC (computer and display composition), cardboard and paper (boxes containing office paper, located near the ignition source); these materials explain both the extremely fast fire propagation and the release of a significant amount of smoke and toxic gases. The grids used in computations would have a major impact on the simulation results. In order to select an appropriate cell size, three grids (20 cm, 10 cm and 5 cm) were tried in the computations. The results from 20 cm cell size have the largest deviations in these computations. At the fire plume area, the results from 10 cm cells and 5 cm cells are close to each other. Using a cell size of 5 cm, the computational time was highly increased, so the 10cm cells were used in this paper.

The same cell size was also chosen by Novozhilov in the simulation of sprinkler interaction with a fire ceiling jet (O'Grady and Novozhilov, 2009) and by Zhang and Chow (Zhang and Chow, 2013).

In order to study the time distribution of the temperature inside the analyzed space, there have been used a number of 8 virtual devices (thermocouples), placed in the central point of the room, on a vertical axe, evenly distributed between 0.6 and 2.7m high.

FDS permits to study the smoke layer characteristics, by using a layer zone device. Layer height is an approximation that is more used in two-zone models than CFD models. Layer height offers an approximation for where the hot and cold gas layers interact. In real fires, this region is not a distinct line, but estimations for a distinct elevation can be calculated, also the lower and upper temperatures for the smoke layer.

The temperature distribution, the air masses movement and the smoke visibility were also being monitored, by using planar slices, located at 2.5m on the X-axis and at 0.7m on the Y-axis. The wall temperature was registered as boundary quantity parameter.

For the studied case, there were simulated three different situations: room fire without any sprinkler system, fire with one sprinkler head placed in the middle of the room, under the ceiling level, and fire with the same sprinkler head, but placed 1 m closer to the fire source location. The sprinkler characteristics are specific for the residential type of sprinklers: generic residential spray model, with conical distribution, water flow rate: 49.05L/min, jet stream velocity: 5.0 m/s and a spray angle of 75°. The sprinkler head activation temperature was set to 68.33°C, with a response time index of 50.0  $\text{m}^{1/2}\text{s}^{1/2}$ , falling in the class of fast response sprinklers (according to NFPA).

The fire source is presented in Fig. 3. Typical results of fire development and temperature distributions are shown in Fig. 4. Fig. 5 presents the evolution in time for the total Heat Release Rate for the three cases analyzed.

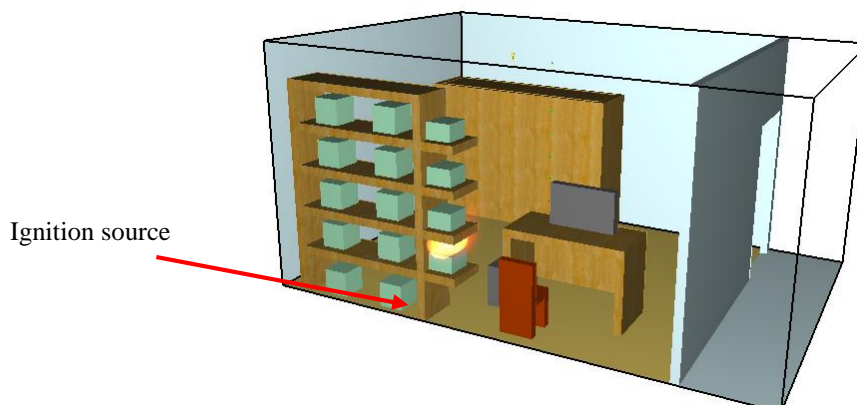


Fig. 3. Ignition source location



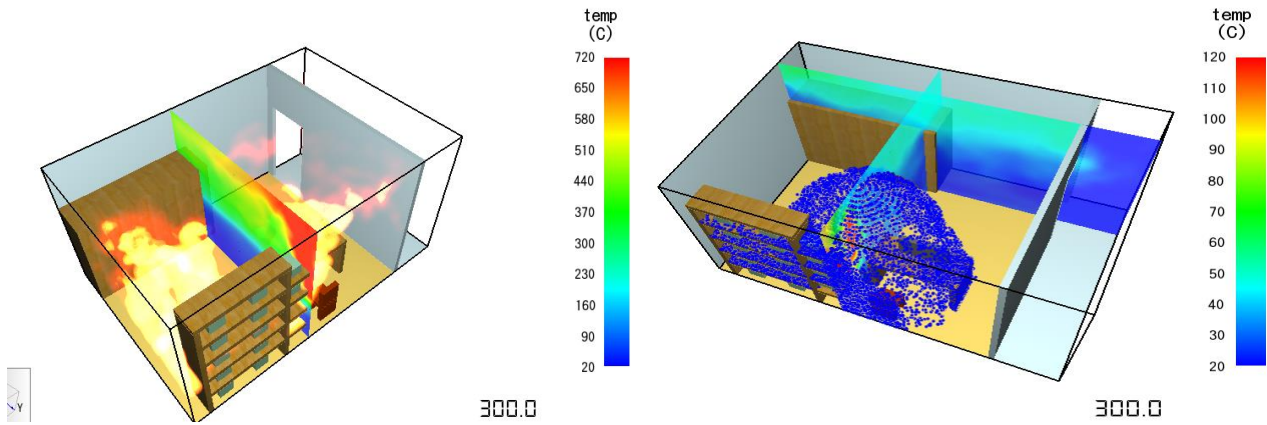


Fig. 4. Fire spreading and temperatures slices for the 1<sup>st</sup> case (no sprinkler), respectively for the 3<sup>rd</sup> case (sprinkler closer to the ignition source location)

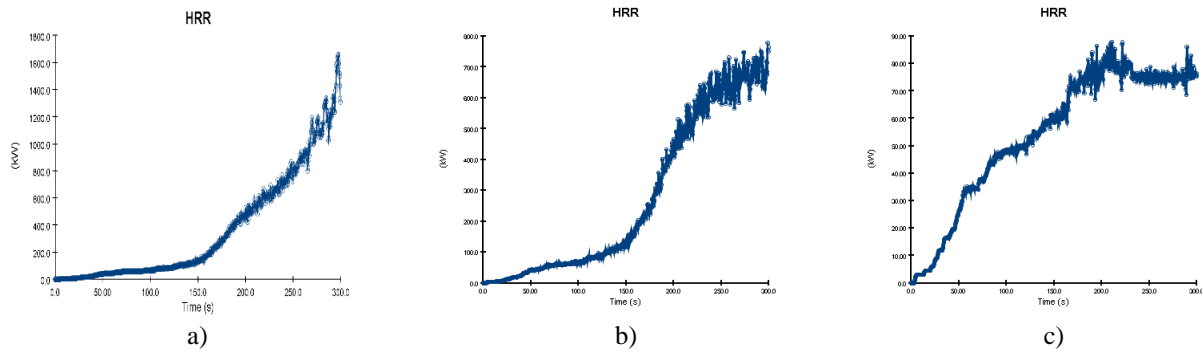


Fig. 5. Heat Release Rate for the three cases analyzed.

From the three cases studied, there could be observe that the presence of the sprinkler head in the office room plays a crucial role in cooling down the room temperature, and also limiting the heat released in fire. In FDS, if the governing burning reaction is well defined, or if the extinguishing coefficient for every material that participate to the fire is specified, water droplets can not only limit the flame spreading, but also suppress the fire.

The smoke layer temperatures present an almost linear decrease to the sprinkler working pressure.

At about 150 s after the fire ignition, a steady smoke layer was formed and the hot smoke flowed out across the upper part of the door (Fig. 6a). There was a clear smoke-air interface at about 1.2-1.5 m above the floor. From the ceiling to smoke-air interface, the temperature declined smoothly. The situation changed when the sprinkler was activated. Due to the cooling effect and the drag force on the smoke, the temperature would decrease apparently. The smoke would not keep on the ceiling and move downward (Fig. 6b). The soot visibility and temperatures in the door direction were favorable when the sprinkler were used, permitting the evacuation in good conditions for the potential occupants (Ghicioi et al., 2018).

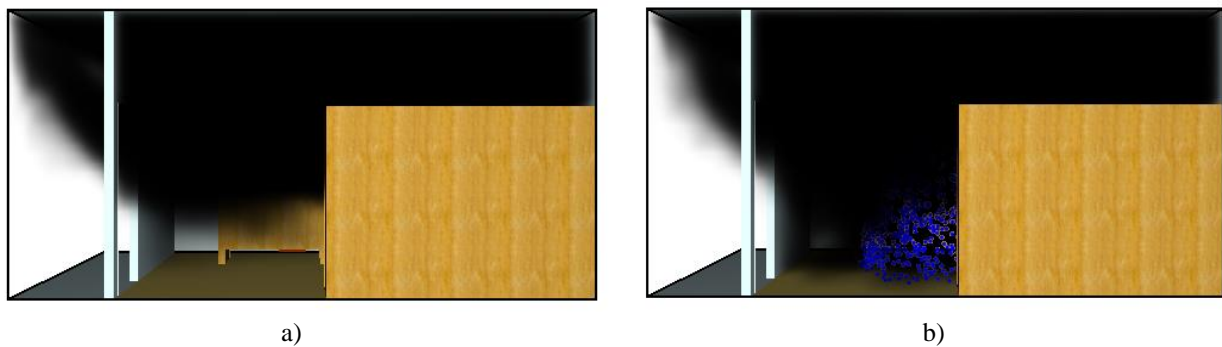


Fig. 6. The smoke layer in different conditions. a) before sprinkler activation; b) after sprinkler activation.

## 4. Conclusions

The interaction of fire smoke and the water spray was studied in this paper. Fire Dynamics Simulator version 6.6.0 (FDS), software developed by NIST, was used for the numerical simulation. A number of 3 cases, room fire without water suppression and using sprinkler located in different positions were analyzed. The following observations are made:

- after sprinkler activation, the temperature inside the room would decrease under the cooling effect of the water droplets;
- the sprinkler capability to extinguish the fire depends on the sprinkler head position relative to the zone affected by fire;
- comparing with the condition before sprinkler activation, the smoke temperature after sprinkler activation at the same height was significantly lower.
- due to the drag force of water spray, once the sprinkler was activated, the smoke would descend. The smoke–air interface surface would not be kept horizontal. The descend depth depends on the fire heat release rate and the working pressure of the water extinguishing system with sprinkler.

## 5. Acknowledgements

This paper was developed within the Nucleu Programme, carried out with the support of the Ministry of Research and Innovation - MCI, project no. PN 18-17-01-01, Development of institutional capability for technical expertise of explosion / fire type events – EXTOX (in Romanian).

## References

- Friedman, R., *Theory of fire extinguishment*, NFPA Fire Protection Handbook -18th Edition, (1997).
- Ghicioi, E., Găman, G.A. et al., *Development of institutional capability for technical expertise of explosion / fire type events – EXTOX* (in Romanian), project no. PN 18-17-01-01, carried out with the support of the Ministry of Research and Innovation – MCI, (2018).
- Vaari, J., Hostikka, S., Sikanen, T. and Paaanen, A., *Numerical simulations on the performance of water-based fire suppression systems*, VTT Technology 54, (2012).
- McGrattan, K., Hostikka, S., McDermott, R., Floyd, J., Vanella, M., *Fire Dynamics Simulator User's Guide*, NIST Special Publication 1019, Sixth Edition, (2018).
- Carlsson, E., *Comparison of Sprinkler Activation in Flat and Sloping Ceilings using FDS 6*, Department of Fire Safety Engineering and Systems Safety, Lund University, Sweden, Report 5404, (2013).
- O'Grady, N., Novozhilov, V., *Large Eddy Simulation of Sprinkler Interaction with a Fire Ceiling Jet*, Combustion Science and Technology 181(7), p. 984, (2009).
- Șuvar, M.C., Păsculescu, V.M., Vlasin, N.I., Lupu, C., Ghicioi, E., *Possibilities to optimize computer simulation of compartment fires*, Proceedings of the 15th International Multidisciplinary Scientific Geoconference SGEM 2015, Section Informatics, Geoinformatics and Remote Sensing, Volume I, 18-24 June 2015, Albena, Bulgaria, ISBN 978-619-7105-34-6, ISSN 1314-2704, pp. 249-256, (2015).
- Zhang, C., Chow, W., *Numerical studies on the interaction of sprinkler and smoke layer*, The 9<sup>th</sup> Asia-Oceania Symposium of Fire Science and Technology, Procedia Engineering 62, pp. 453-562, (2013).

## Improving the quality for classification of pyrotechnic articles on the basis of pyrotechnic composition content

Ilie Ciprian Jitea<sup>\*</sup>, Gabriel Vasilescu, Robert Laszlo, Cristian Raul Cioara, Claudia Miron

*National Institute for Research and Development in Mine Safety and Protection to Explosion-INSEMEX Petrosani, 32-34G-ral. Vasile Milea Street, 332047 Petrosani, Romania*

---

### Abstract

The applicable legislative framework for pyrotechnic articles as regards the placing on the market and use of these products safely is regulated both at national level (Law 319/2006 on Safety and Health at Work with subsequent amendments; Law 126/1995 on the regime of explosive materials and Technical implementation rule, with subsequent amendments), and at European level (through Directive 2013/29 / EU) which states the principles to be applied for insurance the legality for performing operations with explosive materials, the sale, handling and use of pyrotechnic articles, as well as the registration and authorization to carry out the operations with them, in order to avoid personal injury, damage to property or damage to the environment. Thus, according to the regulations in force pyrotechnic articles are classified into different categories depending on the level of risk, taking into account their place of use and destination (in accordance with Article 5 of the Technical Implementation Rule 126/1995 on the regime of explosive materials). Also, pyrotechnic articles are products that present a specific risk to the supplier due to the mode of operation and the quantity / content of the pyrotechnic composition involved, and the possession, marketing and use of such products whose security quality is not legally guaranteed are the object of unlawful actions or the source of risk factors that may affect the security of individuals, material assets and the environment. Also, a number of technical information and data related to security parameters (NEC, safety distances) must be taken into account on the basis of pyrotechnic articles which must be scientifically determined using high-performance equipment to get verosimiles results.

*Keywords:* pyrotechnic composition, pyrotechnic articles, categories

---

### 1. Introduction

According to the literature, pyrotechnics is the science, technique and art of creating, maintaining and controlling fire. Studying, designing and developing pyrotechnic compositions or devices requires in all situations thorough studies theoretical and experimental. The use of pyrotechnic compositions for the generation of heat, light, sound or projectiles, or rockets was possible after "black powder" discovery. The use of pyrotechnic articles has become more and more frequent in recent years throughout the world for the celebration of significant cultural and religious events, the most famous and common being the fireworks. Pyrotechnics can also be used for special effects at concerts, theater performances, film and sporting events, and even rocket launches (CORE Programm PN 16 43 03 04; Jitea I., C., Vasilescu G., Kovacs A., et.al. 2016; Cioara C., R., Șuvar M, C., Morar M., S., Jitea C., 2018).

### 2. Theoretical and practical considerations regarding the determination of the content of pyrotechnic articles

Established methodology from a technical - scientific point of view which has been regulated on the basis of the applicable harmonized referenced and transposed in an accredited work procedure, aims at assessing the net mass of pyrotechnic mixture of pyrotechnic articles by separating the pyrotechnic mixture and weighing it with a suitable technical balance in order to obtain precise results with superior veracity on the result indicators. First of all, the separation of the pyrotechnic mixture takes place which occurs as a result of the sectioning operation, splitting the pyrotechnic article by facilitating the removal of packaging and related ballast. Second, to determine the nature of the load and appreciation for considering it as being or not pyrotechnic mixture, is taken from the quantity resulting from 1

---

<sup>\*</sup> Corresponding author. +4-0731-390-812; fax: +40-254-545-277.  
E-mail address: ciprian.jitea@insemex.ro.

÷ 2 g of the material considered to be pyrotechnic, after which it is introduced into a crucible and the test is followed by the direct contact with the flame open if there is a reaction after this contact is then considered to be a pyrotechnic composition and in the opposite sense it is appreciated as if lest. In order to ensure an adequate health and safety climate, these tests are carried out on the basis of a technical work procedure accredited by trained personnel and with the appropriate technical expertise only in specially designed spaces. Exceptionally, if the pyrotechnic article subjected to the technical expertise of the sectioning operation can not be safely performed, then the determination of the net mass by difference, obtained by subtracting from the total (initial) mass of the pyrotechnic article determined by weighing it before consumption of pyrotechnic substance by the test of operation and the resulting mass of the pyrotechnic product after the pyrotechnic article has been subjected to the operational test (the packaging and the inert material remaining after the test). In order to carry out the test according to the principles of quality and rigor of the operations required by the recognition of accreditation attributed to the field of competence of the specialized laboratory, sampling and sample preparation shall be carried out in the explosive handling room and the tests shall be carried out individually on each individual product in the form were delivered by the manufacturer. Also for separating the net mass of the pyrotechnic composition from the package, the packaging is cut into the area where is the most readily accessible the cargo is and the pyrotechnic composition content is drained without being polluted by the material lest. However, is done the tare of the balance and of the vessel in which the pyrotechnic composition is emptied, and the pyrotechnic composition content is then weighed, after which are noted the results obtained in the primary data register. The result indicators obtained from the testing of the content of the pyrotechnic articles may be used for framing the pyrotechnic articles in categories according to the provisions of Art.5 (1) of the Technical Norms to Law 126/1995, as subsequently amended and supplemented, Art. 7. of Decision no. 1102/2014, SR EN 15947 - 2: 2016, SR EN 15947 - 4: 2016 respectively SR EN 15947 - 5: 2016, (Cioara C., R., Kovacs A., Morar M. S., Jitea C. I., Rădeanu C., 2018; Directive 2013/29/EU, 2013; Jitea I.C., Kovacs A., Vasilescu G., et.al., 2017)

### 3. Results of determination of the contents of pyrotechnic articles OBJECT TESTED (description and identification):

In order to determine the content of pyrotechnic articles, two types of articles have been technically examined, namely:

- Roman candle (Description: tube containing alternate propellant charges, pyrotechnic units and transmitting fuses.), shown in Figure 1

- battery (Description: Battery: assembly which includes elements such as shot tubes of the same type and size that are in category F2, which has a parallelepipedal shape (150/122/125 mm), 1 initial fuse, 16 shot tubes tubes) and 9 shot tubes (inner tubes), material: cardboard, paper, ballast material) shown in Figure 2.



Fig.1- Roman Candles F2 – 5 skuds romerlyls

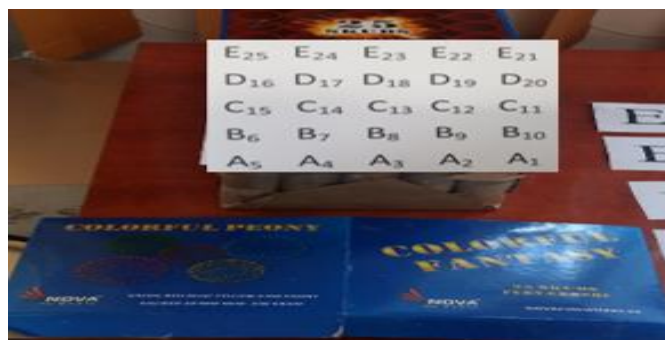


Fig.2- Battery F2 - Colourfull Peony

The results determined from the tests performed are summarized in table no. 1 for Roman candles and in table number 2 for battery.

Table 1

Commercial name/ Product/ Type	Sample No	Weight of lift charge	Weight of burst charge	Weight of pyrotechnic effects		Total Weight/tube	Total weight of pyrotechnic composition in item (Total NEC)
		[g]	[g]	[g]		[g]	
5 skuds romerlys / 1008 – F2 – 69250006/ Roman Candles	1	A	2.00	1.14	3.53	0.60	7.27
		B	1.98	0.96	3.79	0.57	7.30
		C	1.84	1.26	4.77	0.42	8.29
		D	1.79	0.95	3.26	0.80	6.80
		E	2.07	1.38	3.47	0.77	7.69
	2	A	1.88	1.12	3.68	0.41	7.09
		B	1.95	0.96	3.51	0.39	6.81
		C	1.78	1.14	4.21	0.73	7.86
		D	1.93	1.15	3.54	0.58	7.20
		E	1.85	0.86	2.70	0.34	5.75
	3	A	1.95	1.15	3.59	0.52	7.21
		B	1.86	0.89	3.91	0.63	7.29
		C	1.64	1.20	4.51	0.58	7.93
		D	1.83	1.08	3.43	0.77	7.11
		E	1.98	1.32	3.29	0.63	7.22

Table 2

Commercial name/ Product/ Type	Sample No.	Tubes	Weight of lift charge	Weight of burst charge	Weight of pyrotechnic effects		Total weight/ tube	Total weight/ Tubes	Total weight of pyrotechnic composition in item (Total NEC) [g]	
			[g]	[g]	[g]	[g]	[g]	[g]		
Colourfull Peony / 1008-F2- 69252064/ Battery	1	A	A1	2.30	0.57	4.14	0.54	7.55	38.73	192.31
			A2	2.29	0.67	4.39	0.52	7.87		
			A3	2.22	0.68	4.39	0.54	7.83		
			A4	2.20	0.68	4.38	0.62	7.88		
			A5	2.23	0.63	4.21	0.53	7.60		
		B	B6	2.37	0.67	4.29	0.54	7.87	37.89	
			B7	2.10	0.64	4.12	0.40	7.26		
			B8	2.12	0.51	4.35	0.44	7.42		
			B9	2.17	0.55	4.26	0.70	7.68		
			B10	2.17	0.61	4.42	0.46	7.66		
		C	C11	2.12	0.63	4.34	0.68	7.77	39.20	
			C12	2.14	0.66	4.11	0.49	7.40		
			C13	2.41	0.64	4.70	0.61	8.36		
			C14	2.19	0.74	4.22	0.67	7.82		
			C15	2.16	0.65	4.60	0.44	7.85		
		D	D16	2.15	0.60	4.21	0.45	7.41	37.81	
			D17	2.16	0.67	4.30	0.50	7.63		
			D18	2.19	0.65	4.31	0.43	7.58		
			D19	2.22	0.70	4.15	0.45	7.52		
			D20	2.15	0.50	4.48	0.54	7.67		
		E	E21	2.21	1.12	4.05	0.31	7.69	38.68	
			E22	2.29	1.22	3.73	0.40	7.64		
			E23	2.19	1.15	3.77	0.55	7.66		
			E24	2.26	1.01	4.00	0.53	7.80		
			E25	2.19	1.07	4.29	0.34	7.89		
2	A	A1	1.76	0.81	4.92	0.47	7.96	38.40	197.24	
		A2	1.51	0.83	4.16	0.52	7.02			
		A3	2.10	0.76	4.07	0.49	7.42			

Commercial name/ Product/ Type	Sample No.	Tubes	Weight of lift charge	Weight of burst charge	Weight of pyrotechnic effects		Total weight/ tube	Total weight/ Tubes	Total weight of pyrotechnic composition in item (Total NEC) [g]			
			[g]	[g]	[g]		[g]	[g]				
Colourfull Peony / 1008-F2-69252064/ Battery	3	B	A4	2.04	0.80	4.01	0.55	7.40	39.43	199.05		
			A5	2.08	1.31	4.63	0.58	8.60				
			B6	2.23	0.94	4.46	0.49	8.12				
			B7	2.29	0.90	4.36	0.47	8.02				
			B8	2.36	0.91	3.92	0.50	7.69				
		B9	2.27	0.96	4.34	0.43	8.00					
		B10	2.20	0.93	3.95	0.52	7.60					
		C	C11	2.33	0.78	4.24	0.52	7.87	41.46			
			C12	2.24	1.09	4.57	0.58	8.48				
			C13	2.23	0.95	4.72	0.54	8.44				
			C14	2.39	0.78	4.60	0.61	8.38				
			C15	2.22	0.80	4.69	0.58	8.29				
		D	D16	2.35	0.70	4.21	0.45	7.71	38.70			
			D17	2.26	0.67	4.30	0.50	7.73				
			D18	2.29	0.75	4.31	0.43	7.78				
			D19	2.22	0.70	4.15	0.45	7.52				
			D20	2.25	0.69	4.48	0.54	7.96				
		E	E21	2.31	1.01	4.16	0.34	7.82	39.25			
			E22	2.30	1.19	3.73	0.42	7.64				
			E23	2.29	1.08	3.85	0.65	7.87				
			E24	2.28	1.02	4.04	0.58	7.92				
			E25	2.25	1.13	4.31	0.31	8.00				
				A	A1	2.40	0.71	4.36	0.57		8.04	39.84
					A2	2.31	0.73	4.39	0.50		7.93	
					A3	2.38	0.68	4.22	0.67		7.95	
A4	2.25				0.67	4.31	0.68	7.91				
A5	2.30				0.76	4.34	0.61	8.01				
B	B6			2.29	0.68	4.40	0.63	8.00	39.92			
	B7			2.40	0.62	4.59	0.59	8.20				
	B8			2.25	0.65	4.49	0.60	7.99				
	B9			2.30	0.70	4.26	0.56	7.82				
	B10			2.20	0.72	4.32	0.67	7.91				
C	C11			2.31	0.76	4.37	0.58	8.02	39.82			
	C12			2.29	0.80	4.22	0.70	8.01				
	C13			2.25	0.71	4.61	0.62	8.19				
	C14			2.19	0.64	4.33	0.67	7.83				
	C15			2.25	0.66	4.27	0.59	7.77				
D	D16			2.30	0.61	4.28	0.54	7.73	39.01			
	D17			2.19	0.60	4.33	0.59	7.71				
	D18			2.30	0.62	4.25	0.62	7.79				
	D19			2.25	0.48	4.48	0.56	7.77				
	D20			2.26	0.70	4.38	0.67	8.01				
E	E21			2.30	1.02	4.25	0.64	8.21	40.46			
	E22			2.29	1.20	3.90	0.52	7.91				
	E23			2.30	1.05	3.97	0.75	8.07				
	E24			2.29	1.00	4.10	0.68	8.07				
	E25			2.27	1.17	4.35	0.41	8.20				



4. Interpretation of results

From the analysis of the results of the performed tests, the following assessments can be made: (1) three pyrotechnic articles were tested for both types of pirotechnic articles, roman candles as well as for the battery for which 3 kinds of pirotechnic composition were determined (lift charge, burst charge, pyrotechnic effects), obtaining a total value of 37.5 g, 37.41 g and 37.76 g of pyrotechnic composition / article for roman candles (Figure 3) and 192, 31 g, 197.24 g and 199.05 g for battery (figure 4); (2) in accordance with the applicable legislation and taking into account the values obtained in the determination of pyrotechnic articles content, these pyrotechnic articles may be classified in the F2 category, as confirmed by the technical documents certifying the products.



Fig.3- Roman Candles F2 –composition

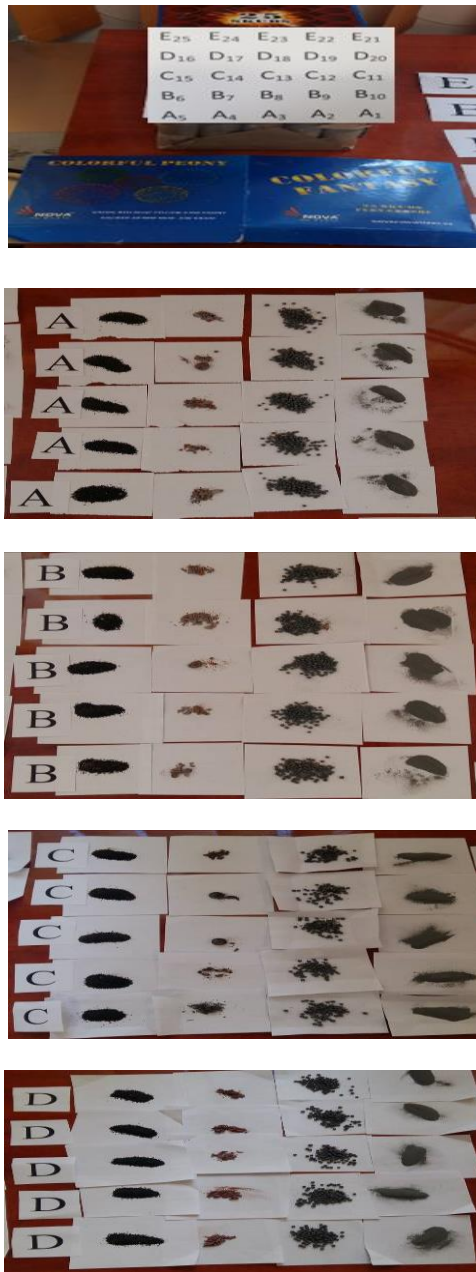




Fig.4- Battery F2 – composition

## 5. Conclusions

The implementation of harmonized standards SR EN 15947 in full compliance with the harmonization of applicable legislation by promoting Decision No. 1102/2014 on the application of the requirements of the European Directive 2013/29 / EU as well as Law 126/95 and the Technical Implementation Norms with amendments and further additions to the testing laboratory in the field of civilian explosives and pyrotechnic articles LMEAP within the GLI - INSEMEX laboratory, accredited RENAR, allowed to provide the technical and administrative framework for the technical tests, assessments and expertise in the field of pyrotechnic articles in accordance with the applicable security requirements.

The tests for determination of pyrotechnic articles content (NEC) were made on two types of pyrotechnic articles of Danish origin, respectively the roman candles and battery using the high-performance technical infrastructure within the INSEMEX polygon, in order to obtain accurate results with high verosimilitude.

Analyzing the data and the results obtained from the tests carried out, it results that these products comply with the requirements of the applicable standard and the technical product documentation.

## References

- Ciprian Jitea, Research on the influence of microclimate factors on parameters of the products, while testing the functioning of pyrotechnic article. PN 16 43 03 04, NRDI INSEMEX
- Cioara C., R., Șuvar Marius Cornel, Morar Marius Simion, Jitea Ciprian Ilie, Vasilescu Gabriel Dragoș „*Development of a sustainable safety degree of the activity with pyrotechnic articles for professional use (F4)*”, Section Environmental Legislation, Multilateral Relations and Funding Opportunities, SGEM, (2018).
- Cioara C., R., Kovacs Attila, Morar Marius Simion, Jitea Ciprian Ilie, Rădeanu Cristian „*Modern training infrastructure for pyrotechnic experts according to the applicable regulations*”, EEMJ, (2018).
- Directive 2013/29/EU of the European Parliament and of the Council of 12 June 2013 on the harmonisation of the laws of the Member States relating to the making available on the market of pyrotechnic articles
- SR EN 15947 - 1 ÷ 5 – Pyrotechnic articles. Fireworks, Categories F1, F2, F3
- Jitea I.C., Vasilescu G., Kovacs A., et.al. *The analysis of the influence of functioning parameters for fireworks and fireworks for professional use*, 7th International Multidisciplinary Symposium „UNIVERSITARIA SIMPRO”, Conference Proceedings, ISSN–L 1842 – 4449, Petrosani, (2016).
- Jitea I.C., Kovacs A., Vasilescu G., et.al. *Prospective analysis of ambiental and weather effects on conform displaying of fireworks*, The 8<sup>th</sup> International Conference on Manufacturing Science and Education June 7 – 9, 2017, Sibiu, România, (2017).



# Prospective and exploratory research in the quality field of industrial risk assessment and analysis

Gabriel Dragoş Vasilescu\*, Robert Laszlo, Attila Kovacs, Cristian Radeanu, Olga Miclea

*National Institute for Research and Development in Mine Safety and Protection to Explosion – INSEMEX, 32-34 G-ral Vasile Milea street, Petroşani, 332047, Romania*

---

## Abstract

Qualitative and/or semi-quantitative risks analysis measures are not able to model and assess the effects of two or more simultaneous faults or the benefits which redundancy may bring to the safety system. One of their shortcomings is the incapacity of being used efficiently for low frequency modelling and predication of events with severe consequences. By approaching the scientific study upon human reliability along with technical and performance data are ensured the premises for developing an innovative tool for dynamic modelling the safety of a complex socio-technical system.

*Keywords:* Bayesian network, industrial risk, monitoring system.

---

## 1. Introduction

Qualitative and/or semi-quantitative risks analysis measures are not able to model and assess the effects of two or more simultaneous faults or the benefits which redundancy may bring to the safety system. One of their shortcomings is the incapacity of being used efficiently for low frequency modelling and predication of events with severe consequences. Examples of quantitative risk analysis models include: Fault Tree Analysis (FTA), Event Tree Analysis (ETA), Level of Protection Analysis (LOPA), First Order Reliability Method (FORM), Monte Carlo simulation, as well as other mathematical models (Covello and Merkhofer, 1993; Lee et al., 2012; Vasilescu, 2010)). Quantitative assessments exceed the shortcomings and are adapted for situations in which are available proper data for the design, exploitation, maintenance or for the modification of a technical or work system. Also, results of quantitative analysis may be used for cost-benefit studies and for demonstrating the fact that risks for workers, industry, society and environment are as low as reasonably practicable (ALARP), especially when the assessment refers to the risks with catastrophic consequences which may be defensively prevented only by quantitative analysis. Therefore, research has to focus on analysing the reliability and opportunity of using quantitative risk analysis methods in the industry. Using performance data will objectively support the assessment and comparison of complex technological systems, testing and assessment of the adaptation capacity in design, exploitation and maintenance. This approach is proper for identifying the vulnerabilities of the system and the mitigation strategies intended for reducing risk exposure, so that by efficient and correct modelling, the changes can be simulated before being put into practice. By approaching the scientific study upon human reliability along with technical and performance data are ensured the premises for developing an innovative tool for dynamic modelling the safety (Vasilescu et al., 2013b; Vasilescu and Mija 2013) of a complex socio-technical system.

## 2. Occupational risk assessment methodology

Probability graphic models and graphs in which the junctions represent random variables and the arches (respectively their lack) represent conditioned independence assumptions (Vasilescu et al., 2012). Therefore, they provide a compact representation of cumulated probabilistic distributions. Risk assessment by using Bayesian networks consists in building

---

\* Corresponding author. +4-072-434-3017; fax: +40-254-545-277.  
E-mail address: dragos.vasilescu@insemex.ro.

up the Bayesian model by taking into account the observations regarding the identified risk factors (work equipment, work environment, work load and performer), based on which are highlighted the formal results of such risks perception depending on the hazardous event's occurrence probability and the maximum predicted severity (Pasculescu et al., 2012). In this regard, there is proposed for example an occupational risk assessment sheet which has been designed by taking into account 4 probability classes and 4 severity classes (as shown in Figure 1 and Table 1 and Table 2):

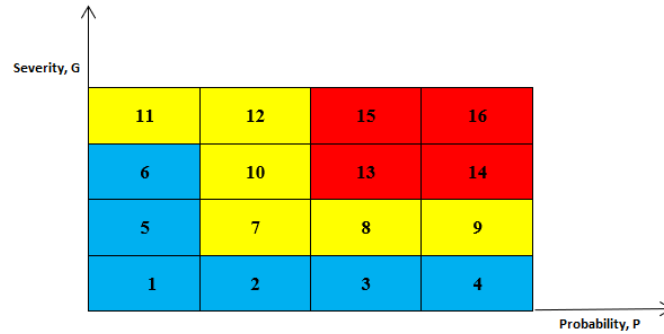


Fig. 1. Occupational risk level assessment grid

where:

Table 1 Risk parameter classes

Severity class		Probability class	
1	Negligible	1	Low
2	Average	2	Average
3	Severe	3	High
4	Very severe	4	Very high

Table 2 Risk level estimation and appreciation

Fuzzy variable $x_m$	Degree of damage $G(x_m) = \exp[-k_{med} \cdot (1 - x_m)]$	Risk level $N_R$
[0.00, 0.33]	[0.035, 0.105]	1÷6
[0.33, 0.66]	[0.105, 0.320]	7÷12
[0.66, 1.00]	[0.320, 1.000]	13÷16

The method consists of several steps: **(P1)** Identification of causal factors generated by work equipment, work environment, work load and performer; **(P2)** Development of the influence diagram which establishes the causality connections between causal factors; **(P3)** Actual development of the influence Bayesian network, determining the causal factors and the causality connections in which they may be involved, establishing the distribution tables; **(P4)** Assessing the risk level by applying the inference.

For achieving the logic of a safety level monitoring system is proposed a model based on bayesian networks which ahs the following shape (Figure 2):

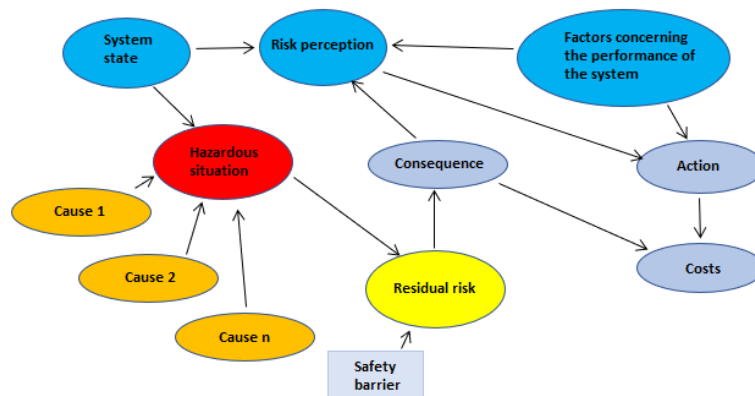


Fig. 2. Risk monitoring model based on Bayesian networks

By implementing this model may be achieved an assessment of a hazard state depending on several observations, being extended up to costs level. Several triggering causes and the state at a given moment of the system may lead to its crossing into a hazardous state. The hazardous state may occur because from the design phase it could not be removed and as a

consequence it is the cause of a residual risk occurrence. The residual risk's behaviour is determined by the hazardous state of the monitoring system and may be weighted or removed by existing safety barriers with consequences upon the human factor, by affecting his integrity and the costs generated by material, production or other losses. Depending on the perception of the risk may be initiated an action which implicitly positively or negatively affects the costs (Vasilescu et al., 2015; Vasilescu et al., 2014; Vasilescu et al., 2013a).

### 3. Monitoring system architecture

For performing the monitoring system are required the following equipment: *Server* – PC connected to the local area network and to the internet, through an incorporated network card, on which the software server application is running; *Video camera* – a video camera connected to the server by USB; *Webcam Server* – video camera connected to a specialized software type Webcam server for online live streaming; *Process computer (Client)* – PC connected to the local area network on which the client software is running; *Data acquisition board* – disposing of 8 analogic input channels, which analogic/digital conversion, of 16 bit resolution, connected by USB to the server or to the process computer which runs the client data acquisition software; *Sensors for measuring: temperature, humidity, carbon monoxide or methane concentration* – connected to the data acquisitions board and *Noise Measurement Equipment* – also connected to the data acquisition board (Pasculescu et al., 2014, and Pasculescu et al., 2015). The software for monitoring hazardous workplaces is intended for processing acquired data and real time assessment by applying the probability model based on the bayesian theory. Data are processed and analysed by using the monitoring software designed for controlling and real time assessing the occurrence of a hazardous situation (Cioclea et al., 2015; Leba et al., 2014) (Figure 3).

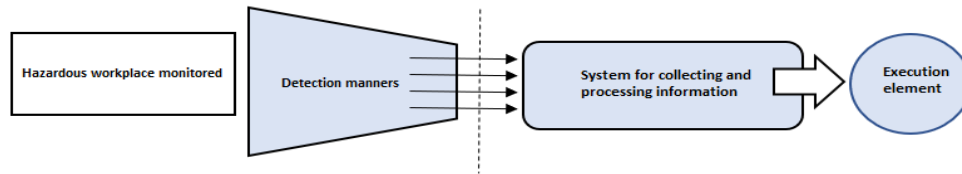


Fig. 3. General structure of a system for monitoring hazardous workplaces

#### 3.1. Hazardous work environment monitoring

##### a) Operation principle

The monitoring subsystem starts from the idea that the essential factors of the work environment (temperature, humidity, noise, gas concentration – CO or CH<sub>4</sub>) may directly or indirectly determine the occurrence of accidents or of occupational disease (Conte et al., 2011, Kotus and Kostek, 2008), in case their values exceed the maximum admitted limits by regulations in force. It contains:

- **Temperature** junction has the following states: *Under/Over MAL* and *Optimal*. If the value collected by the sensor ranges between 18 °C and 24 °C, then it is set and observed the *Optimal* state of temperature, otherwise there is set and observed the *Under/Over MAL* state;

- **Humidity** junction has the following states: *Under/Over MAL* and *Optimal*. If the value read by the sensor concerning the relative Humidity is below 10 %, then it is set as observation the *Optimal* state of humidity, otherwise being set the *Over MAL* state;

- **Noise** junction has the following states: *Under/Over MAL* and *Optimal*. In case the value of the Noise level acquired by the software is below 87 dB(A), then it is set as observation the state of *Optimal* for the noise level, otherwise there is set as observation the *Over MAL* state;

- **Discomfort** junction has the following states: *Yes* and *No*. Depending on the observations concerning temperature, humidity and noise, it sets on the base of the distribution table, the corresponding proofs, as follows (Table 3):

Table 3

Parent junctions for "Discomfort"				
Noise	Temperature	Humidity	Discomfort	
			YES	NO
Optimal	Optimal	Optimal	0.0	1.0
		Over MAL	0.3	0.7
Over MAL	Under/Over MAL	Optimal	0.7	0.3
		Over MAL	1.0	0.0

- **Technical equipment** junction has the following states: *On* and *Off*. Depending on the equipment state at a certain moment, the application sets the proofs corresponding to the state in which the monitoring equipment is found;

- **Gas Concentration** junction has the following states: *Under MAL* and *Over MAL*. In case the value recorded by the sensor for carbon monoxide concentration is lower than 100 ppm, then it is set as observation the *Under MAL* state for gas concentration, otherwise being set as observation the *Over MAL* state;

- **Temperature, Humidity, Noise, Technical equipment, Gas Concentration** junctions are defined as causal independent not having a related distribution table attached;
- **Hazardous event** junction has two states: *Takes place* and *Does not take place*. Establishing the probability for each state of the *Hazardous event* junction is performed based on the following distribution table (Table 4):

Table 4

Parent junctions for „Hazardous event”					
Work system	Discomfort	Gas concentration	Work equipment	Hazardous event	
				Takes place	Does not take place
Affected	YES	Under MAL	On	0.7	0.3
			Off	0.4	0.6
		Over MAL	On	1.0	0.0
			Off	0.7	0.3
Not affected	NO	Under MAL	On	0.3	0.7
			Off	0.0	1.0
Over MAL		On	0.7	0.3	
		Off	0.4	0.6	

The bayesian model proposed for establishing the probability for an unwanted event to occur by meeting the proper conditions for the occurrence of a hazardous situation is presented in Figure 4:

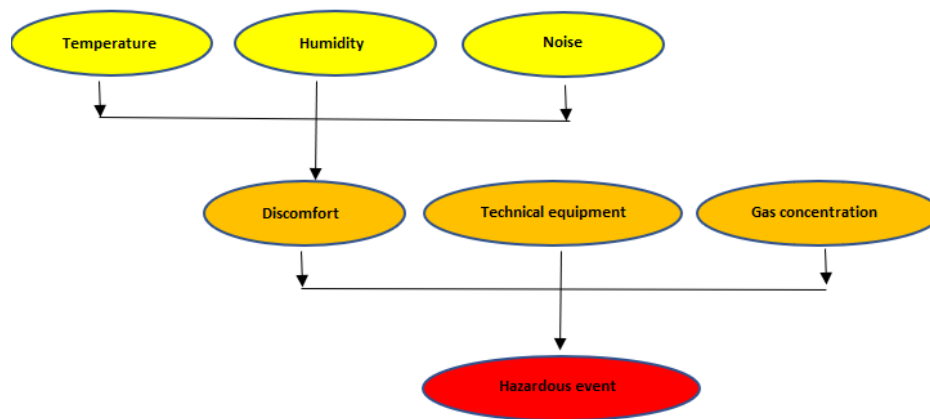


Fig. 4. Model for analysing and assessing the occurrence probability of a hazardous situation which may favour the occurrence of a hazardous event

#### b) Communication protocol

This work environment monitoring subsystem uses client technology. The server comprises the video monitoring system and it is the one to which the values of environmental factors will be transmitted and where alarm signals will be generated. The client is responsible for local acquisition of values through acquisition equipment, the conversion into the correct format, application of the diagnosis model based on bayesian probability and for sending the data to the server.

## 4. Results obtained

Following the analysis and assessment of a work system from industrial spaces with potentially explosive and/or toxic atmospheres there have been identified a number of 43 occupational risk factors (independent or derived) which have been assigned depending on the corresponding work system component and on their manner of manifestation as follows: Work equipment (EM)-19 factors ( $F_{EMi, i=1,19}$ ); work environment (Me)-11 factors ( $F_{Meij, i=1, j=1,2}$ ;  $F_{Mei, i=2,6}$ ;  $F_{Meij, i=7, j=1,2}$ ); work load (SM)-5 factors ( $F_{SMij, i=1, j=1,2}$ ;  $F_{SMi, i=2,4}$ ) and executant (E)-8 factors.

The integrated table comprising the results on the monitoring of hazardous conditions (Tables 5, 6 and 7) and the general conceptual model for the assessment of risks from the analysed work system is presented in Figure 5.

Table 5

Parent junctions for “Work system”		Work system impairment	
		Takes place	Does not take place
Work equipment		0.19	0.81
Work environment		0.10	0.90
Work load		0.07	0.93
Executant		0.09	0.91
<b>Work system</b>		<b>0.11</b>	<b>0.89</b>

Table 6

Parent junctions for "Discomfort"				
Noise	Temperature	Humidity	Discomfort	
			YES	NO
Optimal	Optimal	Optimal	0.0	1.0
		Over MAL	0.3	0.7
Over MAL	Under/Over MAL	Optimal	0.7	0.3
		Over MAL	1.0	0.0

Table 7

Parent junctions for „Hazardous event“					
Work system	Discomfort	Gas concentration	Work equipment	Hazardous event	
				Takes place	Does not take place
Affected	YES	Under MAL	On	0.7	0.3
			Off	0.4	0.6
		Over MAL	On	1.0	0.0
			Off	0.7	0.3
Not affected	NO	Under MAL	On	0.3	0.7
			Off	0.0	1.0
Affected		Over MAL	On	0.7	0.3
			Off	0.4	0.6

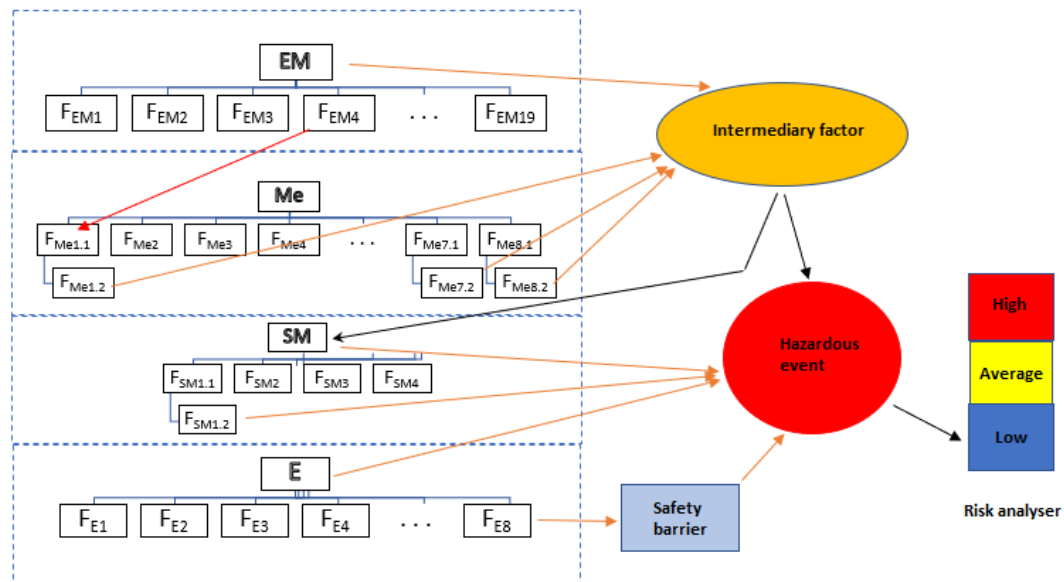


Fig. 5. General conceptual model for occupational risk assessment (EM-work equipment; Me-work environment; SM-work load; E-executant)

## 5. Conclusions

Early identification of hazardous situations during technical faults or emergencies with possible impact upon the health and safety of workers which carry out their activity in hazardous workplaces represents a priority for the OHS field.

The assessment of the OHS level and implicitly of the occupational risk level laid ground for ensuring an efficient risk management system (Babut et al., 2002; Darabont et al., 2002) by the advantages brought along by a computational management system, leading to maximization of the monitoring period and implicitly to the controlled management of risks which may lead to work accidents and/or occupational diseases, as well as to reducing the decisional time and to increasing the rate of revisions for improvement.

By approaching the scientific study upon human reliability along with technical and performance data are ensured the premises for developing an innovative tool for dynamic modelling the safety of a complex socio-technical system.

## References

- Babut, G., Moraru, R., Matei, I., Bancila, N., *Occupational health and safety management systems*, (in Romanian), Focus Publishing house, Petroșani, Romania (2002).
- Ciocea, D., Gaman, G.A., Gherghe, I., Radoi, F., Boanta, C., Pasculescu, V.M., Possibilities to priorly establish the structure of ventilation networks affected by underground explosions, *24th International Mining Congress and Exhibition of Turkey*, pp. 991-997, Antalya, Turkey, (2015).

- Conte, J.C., Rubio, E., Garcia, A.I., Cano, F., Occupational accidents model based on risk-injury affinity groups, *Safety science*, Vol. 49, pp 306–314, (2011).
- Covello, V.T., Merkhofer, M.W., *Risk assessment methods. Approaches for assessing health and environmental risks*, Berlin-Heidelberg-New pringer, Berlin-Heidelberg-New York, (1993).
- Cruz, M., *Operational risk modelling and analysis. Theory and practice.*, published by Risk Book, a Division of Incisive Financial Publishing Ltd, London, (2004).
- Darabont, A., Pece, Ș., Dăscălescu, A., *Occupational Health and Safety Management*, (vol. I and II), AGIR Publishing House, Bucharest, Romania, (2002).
- Kotus, J., Kostek, B., The noise-induced harmful effect assessment based on the properties of the human hearing system, *Archives of Acoustics*, 33, 4, 435-440, (2008).
- Leba, M., Ionica, A., Dobra, R., Pasculescu, V.M., Quality function deployment (QFD) based expert system for renewable energy structures. A wind turbine case study, *Environmental Engineering and Management Journal*, Vol. 13, No. 6, pp. 1365-1370, (2014).
- Lee, H.S., Kim H., Park, M., Construction risk assessment using site influence factors, *Journal of Computing in Civil Engineering*, Vol. 26, Issue 3, pp. 319-330, (2012).
- Pasculescu, D., Lupu, L., Pasculescu, V., Inisconi, I., Suvar, M., Study of electrocution hazards in three-phase electrical networks with ground-isolated neutral point, *Environmental Engineering and Management Journal*, Vol. 11, No. 7, pp. 1267-1271, (2012).
- Pasculescu, V.M., Pricop, D.G., Morar, M.S., Florea V.A., Research on the development of an expert system for selecting technical equipment intended to be used in potentially explosive atmospheres, *15th International Multidisciplinary Scientific Geoconference (SGEM), Informatics, Geoinformatics and Remote Sensing*, Vol. I, pp. 291-298, Albena, Bulgaria, (2015).
- Pasculescu, V.M., Radu, S.M., Ghicioi, E., Pasculescu, D., Niculescu, T., Assessing the safety level of technical equipment operating in potentially explosive atmospheres by using computer modelling, *14th International Multidisciplinary Scientific Geoconference (SGEM), Geoconference on Informatics, Geoinformatics and Remote Sensing*, Vol. I, pp. 43-50, Albena, Bulgaria, (2014).
- Vasilescu, G., Ghicioi, E., Kovacs, A., Gheorghiosu, E., Rus, D., Jitea, C., Csaszar, T., Assessment of occupational risk of exposure to vibrations based on the document for safety to professional vibration, *Applied Mechanics and Materials*, Vol. 801, pp. 230-235, (2015).
- Vasilescu, G.D., Ghicioi, E., Draghici, A., Mija, N., Risk assessment of whole-body vibrations generated by industrial activities with environmental impact, *Environmental Engineering and Management Journal*, Vol.13, No.6, pp. 1327-1558, (2014).
- Vasilescu, G., Ghicioi, E., Simion, S., Pasculescu, V., Model for forecasting the exposure risk of workers to hand-arm occupational vibrations, *Applied Mechanics and Materials*, Vol. 430, pp. 276-280, (2013).
- Vasilescu, D., Kovacs, A., Mija, N., Pasculescu, V., Software for the occupational health and safety integrated management system. *1st International Conference on Intelligent Control, Modelling and Systems Engineering (ICMS'13)*, World Scientific and Engineering Academy and Society WSEAS 2013, 6-8 august 2013, Valencia, Spain, (2013).
- Vasilescu, G.D., Mija, N., Diagnosis and Prognosis of the Hearing Impairment Risk, *Buletinul Institutului Politehnic din Iași, Tomul LIX (LXIII), Fasc.4, Știința și Ingineria Materialelor*, (2013).
- Vasilescu, G.D., Găman, A., Drăghici, A., Simion, S., An efficient integrated method for occupational health and safety internal auditing, applicable to complex working systems in hydroelectric power generation sector, *Environmental Engineering and Management Journal*, Vol.11, No.7, pp. 1221-1366, (2012).
- Vasilescu, G.D., Unconventional methods to analyse and evaluate occupational risk, *Environmental Engineering and Management Journal*, Book Review, Vol. 9, No. 3, pp. 459-460, (2010).

## Research on psychological indicators involved in rescue activities

Izabella Kovacs\*, Daniel Pupăzan, Cristian Nicolescu, Alin Irimia, Andrei Gireadă, Cosmin Ilie

<sup>1</sup>National Institute for Research and Development in Mine Safety and Protection to Explosion – INSEMEX Petroșani,  
32-34 G-ral Vasile Milea Street, Postcode: 332047, Petroșani, Hunedoara County, Romania

---

### Abstract

The organizational environment has always been receptive to what psychologists call individual differences, such as asymmetries that underlie differences between two or more people. Employers are interested in professional qualities and psychic attributes of their employees. In recent years, the emphasis on staff employment has focused on the personality traits of applicants, on intellectual and behavioural qualities they generate. Differences between individuals in attributes such as intelligence, personality and knowledge are important to explain a broad range of outcomes, including academic achievements, managerial, professional, communication with others, etc.

Only the objective knowledge of all individual features and professional requirements and the achievement of an agreement between them can lead to avoiding negative consequences for the individual (such as adaptation disorders, work accidents, burns, etc.). The need to establish this agreement between the individual and work is imperative, especially in the case of activities with increased responsibilities and risks such as intervention and rescue activities.

The paper seeks to identify the psychological indicators that need to be considered in terms of intervention and rescue, both to achieve occupational selection and to plan effective psychological interventions to reduce the effects of occupational stress.

**Keywords:** psychological indicator, rescuer, occupational selection, psychological evaluation

---

### 1. Introduction

As in any other field of activity, psychological examination also represents a precondition for proper management of the work process when it comes to intervention and rescue activities, in order to increase its effectiveness. Psychological assessment of personnel should focus on both individual psychological diagnosis and individual prognosis. Psychological examination reveals the qualities or the presence / absence of professional contraindications and, based on results obtained, the person concerned can be assigned to a particular job.

Only the objective knowledge of all individual features and professional requirements and the achievement of an agreement between them can lead to avoiding negative consequences for the individual (such as adaptation disorders, work accidents, burns, etc.). The necessity of establishing this agreement between the individual and the working activity is imperative, especially in the case of activities with increased responsibilities and risks such as intervention and rescue (situation stipulated by the Romanian legislation in force).

### 2. Particularities of the intervention and rescue activity in toxic/ explosive/ flammable environments

A complete definition of intervention and rescue activity in toxic / explosive / flammable environments may be: a specialized response to an emergency situation that puts lives, material assets and the unit's continuous operation at risk.

---

\* Corresponding author. Phone: +40 254 541 621; Fax: +40 254 546277  
E-mail address: izabella.eisler@insemex.ro

Rescuer's job falls into the "hard work" category, because the effort implies numerous high amplitude oscillations, as far as effort is concerned. The higher their duration, the harder the work is. In addition, the rescue activity is occasional, not permanent, assuming change of the daily skills from the basic profession. Rescuers must undergo training in conditions similar to those in the damaged area, enabling them to act efficiently and safely.

Main tasks in intervention and rescue activity (Kovacs et al., 2017; Pupăzan et al., 2017):

- Respond to alarms of incidents and other requests (industrial accidents, etc.).
- Drive and use machines and equipment necessary for intervention and rescue.
- Identify incident sources by using their knowledge on fire types, construction, building materials, etc.
- Restricting the affected area to prevent unauthorized access.
- Creates openings / breaches in various structures to provide ventilation and access, using axes, blades, saws, ropes, etc.
- Search the area to locate potential victims.
- Rescue victims of the incidents.
- Provide first aid and take measures to resuscitate injured persons.
- Act to identify / find (flammable) chemicals that could cause explosions and fire extensions.
- Inspect and check the location of the incident to ensure there is no danger.
- Performs physical training and simulations to maintain a proper level of training.
- Participate in exercises and demonstrations on intervention and rescue techniques.
- Participate in seminars, conferences and study literature to learn new intervention and rescue techniques.
- Clean and maintenance intervention and rescue equipment.

Also, intervention and rescue personnel in toxic / explosive / flammable environments must have the following skills:

- Exploration of the affected area skills, mapping certain areas, determining the proportion of the damage;
- Execution of various works for isolating the damaged area (construction of interim and / or permanent dams, removal of cave-ins, water pumping and installation of interim claims etc.);
- Operating under special visibility, temperature, workspace and communication conditions;
- Effort under stress and observance of safety and protection rules as well as performing operations such as: construction of buildings for insulation, injured evacuation, and passing through narrow spaces;
- Correct use of protective breathing apparatus;
- Correct handling of machinery, tools and intervention devices skills acquired in the production process;
- Cooperation skills with team members to achieve assigned tasks;
- Ensuring individual and collective security during rescue interventions.

### 3. Psychological particularities of intervention and rescue in toxic/ explosive/ flammable environments

About the psychology of intervention and rescue activity, information can be obtained from various sources, documents and reports, analyzes, scientific papers, etc. In general, there is an acceptable convergence of information obtained from these relatively different sources, in terms of aptitudes and personality profile required by this activity, with different accents on certain groups of psychic attributes, or on how to develop them in the process of preparation and occupational training.

At present, recruitment, expertise, selection and psychological training of personnel is based on the establishment of a minimum of skills, abilities and psychic features (the optimal profile of personality), subjected to an initial and periodic assessment.

In order to identify those psychological indicators that have the greatest relevance in the intervention and rescue activity, a number of 25 people familiar with this activity (i.e. holders of the job concerned, labor analysts, people familiar with the job, trainers and instructors in the field) were questioned. Thus, they were asked to indicate, on a scale of 1 to 7, where 1 is a very small intensity and 7 a very high intensity, the level of intensity involved in the activity of intervention and rescue of a number of 35 abilities. The processing of responses has shown that the most important psychological indicators for the activity under consideration are:

Table 1 Psychological indicators of intervention and rescue personnel (Kovacs et al., 2016)

	Average	Rating
Location of sound	7.19	1
Night vision	7	2
Hearing, physical strength, static force	6.8	3
Recognition of speech, peripheral vision, trunk force, explosive force	6.7	4



Body balance	6.6	5
Hearing sensitivity, depth perception, dynamic strength	6.5	6
Remote visual acuity, dynamic flexibility, reaction time	6.4	7
Vision in brilliant light, close visual acuity	6.3	8
Movement Assignment Coordination, Extension Flexibility	6.2	9
Chromatic vision	6.1	10
Selective attention, spatial orientation	6	11
Distributive attention	5.7	12
Peripheral vision	5.6	13
Self-control, the speed of information structuring	5.5	14
Speed of perception, memory capacity	5.3	15
Flexibility of structure, ordering of information	5.2	16
Categorical flexibility, deductive reasoning, inductive reasoning	5	17
Fluency of ideas	4.9	18

Other sources that refer to the necessary skills for carrying out intervention and rescue activities, such as a series of interviews with people with experience in this field, bring to the forefront the following psychological indicators (most of them representing social / interpersonal groups and emotional abilities) (Boboc, 2017):

Table 2 Psychological indicators of rescuers

	Average	Rating
Seriousness, responsibility, discipline	3.25	1
Courage, spirit of sacrifice	2.8	2
Intelligence, reason, cleverness	2.25	3
Empathy, cooperation, openness, team spirit	1.6	4

The profile of cognitive skills of firefighters, occupation with a high degree of resemblance to the intervention and rescue occupation, developed by “Cognitrom”, is shown in Table 3 ([http://www.cjraetm.ro/images/meserii/pompier\\_specialist.pdf](http://www.cjraetm.ro/images/meserii/pompier_specialist.pdf)).

Table 3 Profile of cognitive skills - firefighter

Skill \ Level of development	Average	Average superior	Maximum
Overall learning ability		X	
Verbal aptitude	X		
Numerical aptitude	X		
Perception of form		X	
Functional skills	X		
Rapidity in reactions			X
Decision-making capacity		X	

Also, for good performance in this occupation, it is also necessary for the following skills to be present, developed at a minimum level: manual dexterity, digital dexterity, eye-hand coordination, instrument control, chromatic discrimination, spatial perception, near and distant visual acuity, strength, flexibility and body extension, static muscle strength.

As far as social / interpersonal skills are concerned, the same “Cognitrom” profile points out that the exercise of this occupation can be achieved by people who are inclined towards things outside their own person, attention oriented to the physical and social environment, action-oriented, ease of communication, sociability. They are conscientious, correct, serious, aimed at clearly defined purposes, manifesting exigency, meticulousness and rigor in carrying out tasks through awareness of rules. They have the ability to maintain their emotional balance in stressful situations without showing extreme manifestations inconsistent with the situation.

Profile organizations, such as the RTDCS (Rescue Team for Disaster and Community Safety), a volunteer organization that was designed to build a society that is aware of all possible disaster that mankind might be subject to, emphasizes that ideally, the rescuer will have the following qualities (<http://www.rescuerangers.org/about-rescue-personal-traits.html>):

- Interest - a real interest in rescue work.
- Training - the desire to continue training to maintain a high professional standard.
- The ability to ensure self-reliance - the lives of victims and team members rely on it.
- Initiative - the nature of rescue operations means that it is often impossible to closely supervise each member of the team. Everyone needs to be able to see what they have to do, set priorities and perform tasks at hand.
- Versatility - every situation is unique. A person must be able to apply a wide range of skills and knowledge in new situations.
- Co-operation - rescue work is usually a team effort, cooperation with others is vital.
- Physical capacity - rescue work of any kind is physically difficult and often continues for long periods of time.
- Driving qualities - driving qualities are required for all rescuers at different times and to varying degrees.
- Control over fears (phobias) - rescuers need to know what they can and cannot do.
- Clothing and wearing - the look must inspire trust in others.

However, if we refer to characteristics necessary for success of rescue activity, evaluated by practitioners themselves, then, according to the results of a study carried out within INCD INSEMEX Petroșani, the situation is shown in Table 4, which presents the positions obtained by each quality, as they were hierarchized by research subjects (grouped in three series A1, A2, A3). The questionnaire stated that 1 is the most important quality and 10 is the least important quality (Pupăzan et al., 2015).

Table 4 Characteristics required to successfully perform rescue activities

Characteristic Serie	High qualification	Experience	Health	Emotional balance	The ability to detect hazards	Occupational interest	Social cooperation	Responsibility	A receptive attitude towards the tasks received	Courage
A1	9	6	1	4	7	10	8	2	3	5
A2	9	7	1	3	6	8	10	2	4	5
A3	9	7	2	6	4	8	10	1	4	3

Therefore, from the analysis of data presented in Table 4 we can state the following (Pupăzan et al., 2015):

- health is considered to be the most important attribute for a rescuer;
- responsibility is the following quality (having the rank of 1-2 depending on the training series);
- social cooperation, high qualification and professional interest were the least important qualities in the perception of subjects;

- there are three qualities (emotional balance, the ability to detect dangers and courage) that have been rated quite differently depending on the three types of training.

Thus, physical health and long-term experience (translated by the high degree of skill development) are the most important characteristics that are self-assessed as necessary in the intervention and rescue activity in toxic / explosive / flammable environments. These are followed by a series of psychological features such as: professional interests, the ability to detect dangers, emotional stability. Of great importance is also high qualification, namely the possession of solid and multiple knowledge regarding the intervention and rescue activity in toxic / explosive / flammable environments.

The conclusions of the study mentioned above are that for the practice of the mine rescue occupation, the individual must have cognitive skills necessary to understand and acquire all the above mentioned knowledge (concentric and distributive attention, memory, analytical reasoning, spatial skills, etc.), physical and mental characteristics which allows him to cope with the great effort he is subjected to, both during training and during interventions (special ability to adapt the body to demands, self-control of stressful situations and full control of behavior) as well as personality characteristics (emotional balance, team spirit, responsibility, devotion, courage, and sometimes even the spirit of sacrifice).

#### 4. Conclusions

The demand on the human body, beyond the limits of an optimal activation, has negative, unfavorable effects because it leads to phenomena such as: fatigue, monotony, saturation, etc. In the case of occupational adaptation difficulties, the human body reacts negatively by developing various pathogenic mechanisms.

Rescuer's job falls into the "hard work" category, because the effort implies numerous high amplitude oscillations, as far as effort is concerned.

In general, there is an acceptable convergence of information obtained from these relatively different sources, in terms of aptitudes and personality profile required by this activity, with different accents on certain groups of psychic attributes, or on how to develop them in the process of preparation and occupational training.

By synthesizing the information obtained from the analyzed sources, we can state that the psychological indicators to be considered in terms of intervention and rescue can be grouped into: cognitive, emotional, social and relational skills. So, summarizing the information obtained from the above-mentioned sources, we can say that the psychological indicators [6] that we must follow in terms of intervention and rescue activities are:

- cognitive abilities (clarity of thinking, concentration, lucidity, attention, linguistic ability, decision, memory, visual-space ability, flexibility in thinking, mental agility, mathematical ability)
- emotional abilities (empathy, emotional stability, adaptation to stress, emotional comfort, impulse control, emotivity);
- social and relational skills (assertiveness, group spirit, respect for others, sociability, tolerance of opposing opinions, conformism, interrelation trust);
- other abilities and skills (vitality, vigilance, ambition, dynamism, courage, altruism, responsibility, perseverance, patience, realism, strength of character, generosity, prudence, sincerity, temperance, self-control, mental calm).

#### Acknowledgements

This paper was developed within the Nucleu-Programme, carried out with the support of Romanian Ministry of Research and Innovation, project no. PN-18-17-02-02, project title: Research on improving health and safety in hazardous environments with explosive, flammable and toxic atmospheres (in Romanian: Cercetări privind îmbunătățirea stării de securitate și sănătate în medii periculoase cu atmosfere explozive, inflamabile și toxice)

#### References

- Kovacs I., Gaman G. A., Pupazan D., Călămar A., Ilie C., *Psychological analysis of work of intervention and rescue activities in toxic / flammable / explosive environments*, Ecology, economics, education and legislation conference proceedings, SGEM 2016, VOL III Book Series: International Multidisciplinary Scientific GeoConference-SGEM pp. 963-969, (2016).
- Boboc M., *Rescuers in action. Documents and accounts of the rescue activity history*, Insemex Publishing House, pp 102-115, (2017).
- Pupăzan D., Călămar A., Găman G.A., Kovacs I., Ilie C., *Importance of mine rescuer's vocational guidance and selection process*, 15th International Multidisciplinary Scientific Geoconference SGEM, Ecology, Economics, Education and Legislation Conference Proceedings, vol. 3, 895-902, (2015).

Kovacs I., Găman G. A., Ilie C., Irimia A., Gireadă A., *Study on cognitive behavioural coping of intervention and rescue personnel in toxic / flammable / explosive environments*, MATEC Web of Conferences, Volume 121 (2017), 8th International Conference on Manufacturing Science and Education – MSE 2017 “Trends in New Industrial Revolution”, Sibiu, Romania, (2017).

Pupazan D., Gaman G.A., Ilie C., Călămar A., Irimia A., Gireada A., *Training methods for intervention and rescue personnel in confined spaces depending on their physiological parameter changes*, Quality-access to success, Volume: 18 Pages: 87-92 Supplement: 1, (2017).

<http://www.rescuerangers.org/about-rescue-personal-traits.html>

[http://www.cjraetm.ro/images/meserii/pompier\\_specialist.pdf](http://www.cjraetm.ro/images/meserii/pompier_specialist.pdf)

# Considerations on low current circuits proficiency tests with explosive gas mixtures

Marius Darie<sup>a</sup> \*, Sorin Burian<sup>a</sup>, Tiberiu Csaszar<sup>a</sup>, Cosmin Colda<sup>a</sup>, Dănuț Grecea<sup>a</sup>

<sup>a</sup>National Institute for Research and Development in Mine Safety and Protection to Explosion – INSEMEX Petroșani, 32-34 G-ral Vasile Milea Street, Petroșani 332047, Hunedoara County, Romania

---

## Abstract

The article is based on the data emerged from a conducted research related to investigations on stochastic behavior of results of tests using spark test apparatus with explosive gas test mixtures. For the purpose of this demarche it was employed a mathematical model for characterization the distance between any two pair set of tests results.

In the first part of the paper was mentioned the spark test apparatus used for the experimentation and were presented the results of the experimental data obtained during the tests.

In the second part was proposed and presented the theoretical model based on Hellinger distance applied to exponential probabilistic distributions of results.

In the third part was exposed results of the used theoretical model. On this occasion was found that proposed distance is adequate for assess the proficiency tests results with explosive gas mixtures.

*Keywords:* proficiency tests; pseudo metrics; probability distributions; explosion probability

---

## 1. Introduction

Usually in the field of power plants but not just here, the industrial activities have a certain degree of exposing to explosion risks.

Due to increased complexity of such technological systems and also due to necessity to operate them safe but also in an efficient manner, those are supervised by a special kind of automatic system. This automatic system of the technological installations are low current systems which comprises sensors, computing parts and executive parts.

Usually, these systems are interfering also with the special spaces endangered by the presence of flammable substances called zones.

Consequently, these systems obey to explosion protection rules especially but not exclusive represented by the intrinsic safety type of protection.

The process of certification of such intrinsically safe systems involve also tests done in presence of explosive gas mixtures.

Next, the paper is focusing on the possibility to assess of such proficiency tests.

Previous results (Darie, 2012), (Johansmeyer, 1994) underlined that the results of such tests have stochastic behavior characterized by an exponential probability density distribution.

For the purpose of experimenting the new proposed theoretical model for proficiency testing assessment was used the data resulted from a previous research. The aim of that research was the investigation of moisture influence over the ignition sensitivity of explosive gas mixtures prepared with methane and air.

Also, that results were found as being adequate for assessing the explosion risk in coal mines.

In that mines, characterized mainly by one-dimensional development (galleries) the propagation of explosion is characterized by the occurrence of pre-compression phenomena and the increase of the speed of propagation in the

---

\* Corresponding author. Tel.: +4 0729 499 084  
E-mail address: Marius.Darie@insemex.ro.

explosion wave front. Those particular aspects lead to casualties and material losses. But also, explosions, in the underground, damage the ventilation system. Consequently, the capacity of exhausting the methane emissions together with the capacity of providing the required fresh air to the workers caught in the associated underground mine works could be severely affected (Cioclea, 2015).

The variations in the ignition probability due to the moisture of air used for preparation of the explosive test gas mixture will be used in this paperwork as perturbations which generate independent set of tests assigned, for the scope of this paper, to different participating laboratory in the proficiency test program.

## 2. Presentation of experimental data

A spark test apparatus (IEC Standard 60079-11, 2012) was employed together with a relative humidity transducer for the inlet air.

According to a specific standard an 8,3% air-methane test mixture was used during the tests, having the air relative humidity values at the air inlet between  $11 \div 38\%$  RH.

Also, the parameters of the electric circuit in which the spark test apparatus has been connected were  $U_0=24V_{cc}$ ,  $L=121mH$ ,  $I_0=110\div111mA$ .

During the tests the inlet air moisture changed according due to weather and the values are shown in the diagram in Figure 1. In the same diagram the value of the number of rotations of tungsten wires holder at which the ignition occurred is also shown. It was performed tests in rainy days (increased moisture) and also in sunny days (lower values of moisture).

In the process of testing, due to the time constant of the humidity sensor, were assigned stabilized red value of relative humidity for every 15 tests done.

Before all tests, conditioning of the cadmium disk of the test rig were performed, according to specific standard.

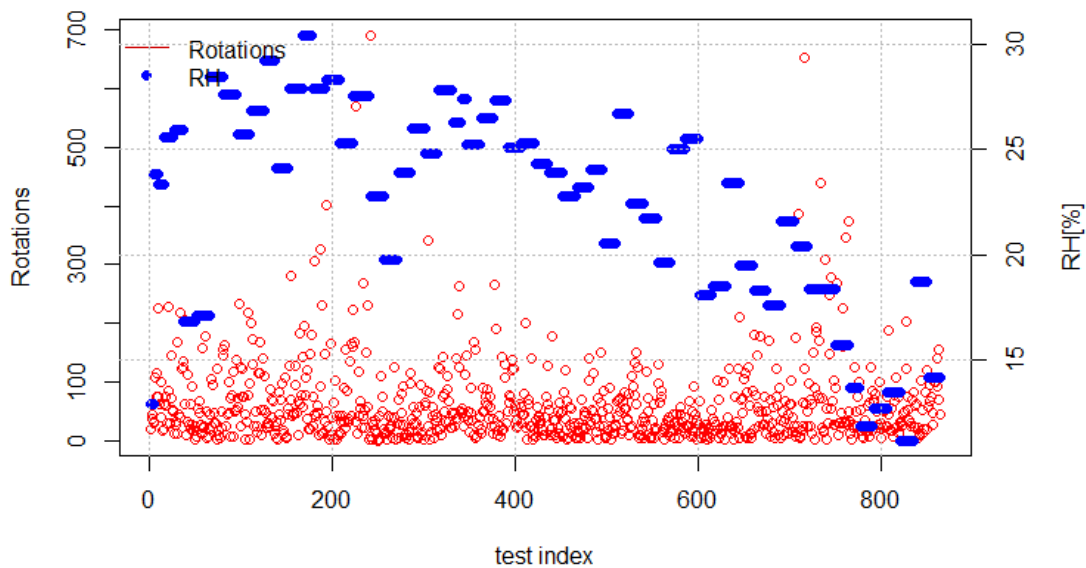


Fig. 1. Inlet air moisture values and the rotations number at which the ignition had occurred

## 3. Proposed theoretical model

In order to quantize the ignition sensitivity for each participating laboratory is proposed using the ignition probability computed according to equation (1).

$$p = \frac{1}{4 \cdot \text{mean}(R)} \quad (1)$$

where  $p$  is the ignition probability and the vector  $R$  is the set of rotations number at which ignition occurred for each laboratory.

For the purpose of investigation of the similarity of the probability values obtained from each lab, has been proposed a new theoretical model based on Hellinger distance (Wikipedia, 2018) applicable to density probability distributions as it is shown in equation (2).

This equation also takes in account the exponential probability distribution of test results values.

$$Hellinger(m_1, m_2) = \frac{1}{2} \sqrt{\int_{-\infty}^{\infty} \left( \frac{e^{-\frac{x}{2 \cdot m_1}}}{\sqrt{m_1}} - \frac{e^{-\frac{x}{2 \cdot m_2}}}{\sqrt{m_2}} \right)^2 dx} = \frac{\sqrt{2} |\sqrt{m_1} - \sqrt{m_2}|}{\sqrt{m_1 + m_2}} \quad (2)$$

where  $m_1$  and  $m_2$  are the mean of test results values for each laboratory.

Consequently, if we consider  $k=m_1/m_2$  then the equation (2) became the equation (3)

$$Hellinger(m_1, m_2) = Hellinger(1, k) = \frac{\sqrt{2} |1 - \sqrt{k}|}{2 \sqrt{1+k}} \quad (3)$$

Also, the equation (2) and (3) underline the commutativity property.

In order to obtain the expected value “c” was considered the equation (4) which is an optimum problem.

$$\sum_{i=1}^n Hellinger(R_i, c)^2 \rightarrow \min \quad (4)$$

Having in view Hellinger distance was proposed data transform presented in the equation (5).

$$T_{Hellinger}(x) = sign(x - c) \cdot Hellinger(x, c) \quad (5)$$

where: sign is the signum function which return the sign of a number;

The raw data was processed by selecting all test results having exactly each 15 identical values for relative humidity. Then was computed ignition probability and assigned all 36 values obtained to a virtual laboratory. Obtained ignition probability values is shown in the Figure 2.

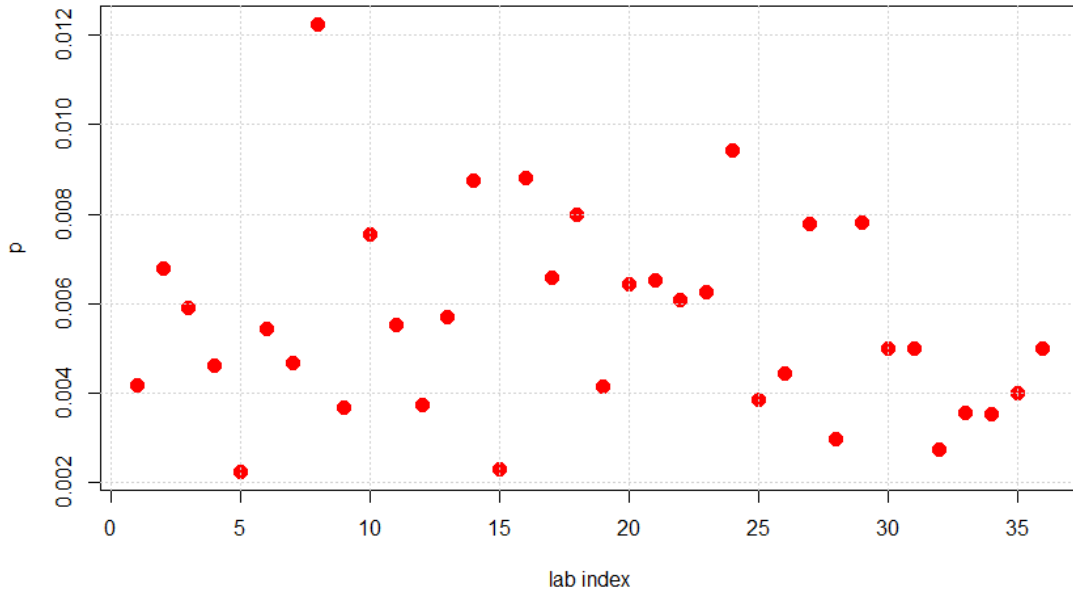


Fig. 2. Ignition probability assigned to each virtual laboratory

The distribution of ignition probability values assigned to each virtual laboratory is presented in Figure 3.

The Figure 3 shows that the skewness is moderate even the data comes from exponential distribution because of central tendency of averaging process implied to obtain the ignition probability.

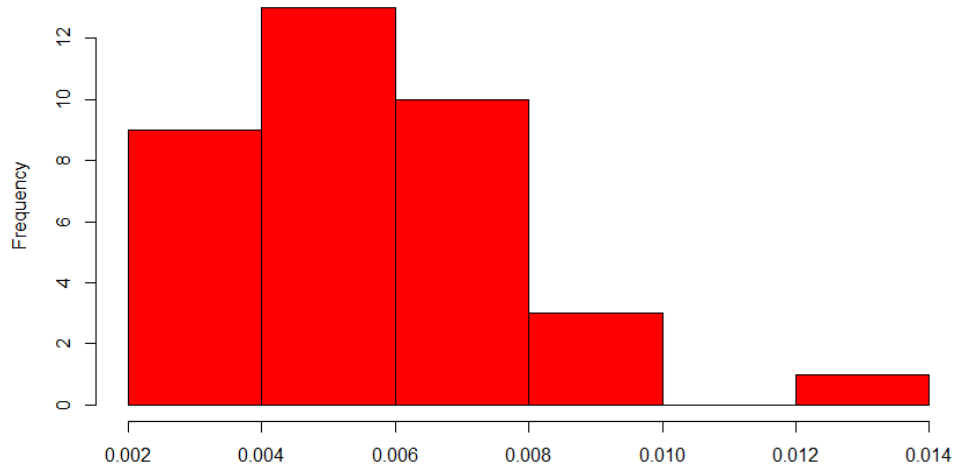


Fig. 3. Histogram of ignition probability values assigned to each virtual laboratory

#### 4. Results and discussions

After using the theoretical model on the experimental data were obtained the results presented in the form of dendrogram in Figure 4.

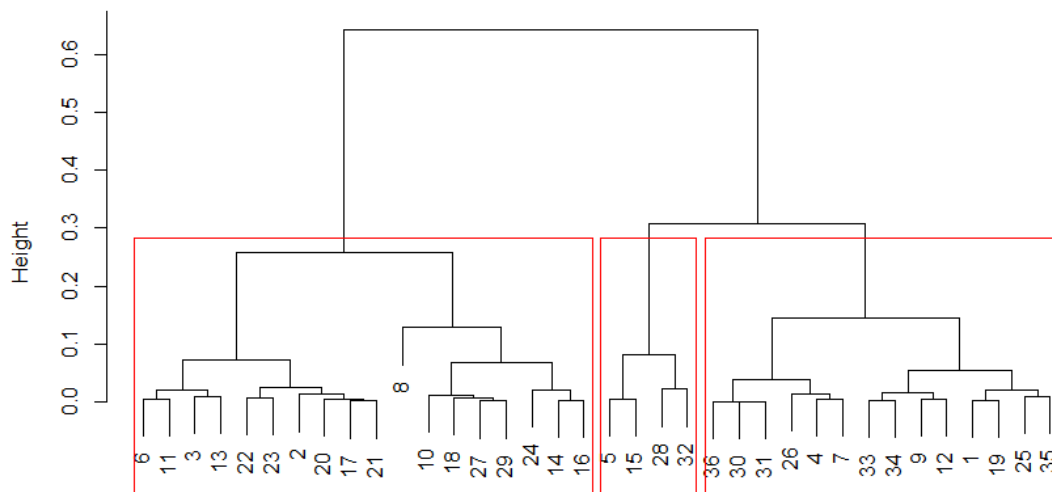


Fig. 4. Dendrogram of clustered results using Hellinger distance and ward D2 algorithm

The red rectangles are automatically chosen in order to obtain 3 clusters.

Having in view the Hellinger distances between clusters shown by the dendrogram in Figure 4 the experimental data could be easily split in two or three clusters.

Additional, analysis done underlined a very interesting aspect emerged by simulation, that the using of the Hellinger distance makes the results being uninfluenced in process of this cluster classification even at the input was applied the transformed data by using decimal logarithm. Also, this distance preserves the relative separation of the clusters. The logarithm transform is already used for exponentially or heavy positively skewed distributed data.

The diagram in Figure 5 show that the cluster number 1 collected the central values.



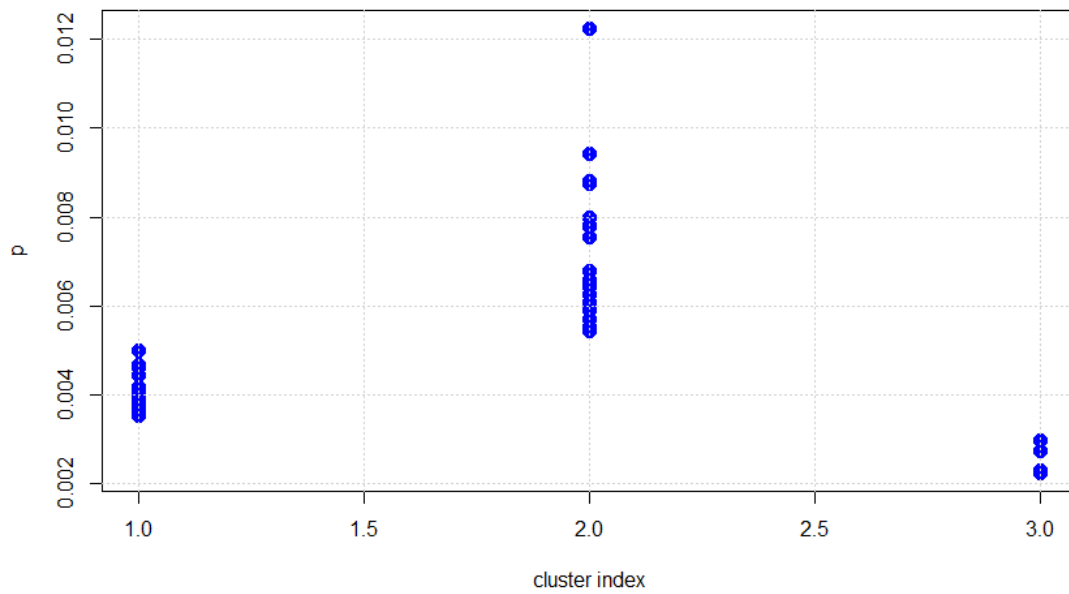


Fig. 5. Distribution of clustered results using Hellinger distance and ward.D2 algorithm

In the table 1 is presented the synthesis of results. Analysis of border between the ranges of clusters could indicate empiric limits of favorable results.

Table 1 Synthesis clustering process

Cluster / Parameter	1	2	3
Mean	0.004245286	0.007314909	0.002566244
Range	0.003521954÷0.005010020	0.005442671÷0.012244898	0.002244837÷0.002989835
Size	14	18	4

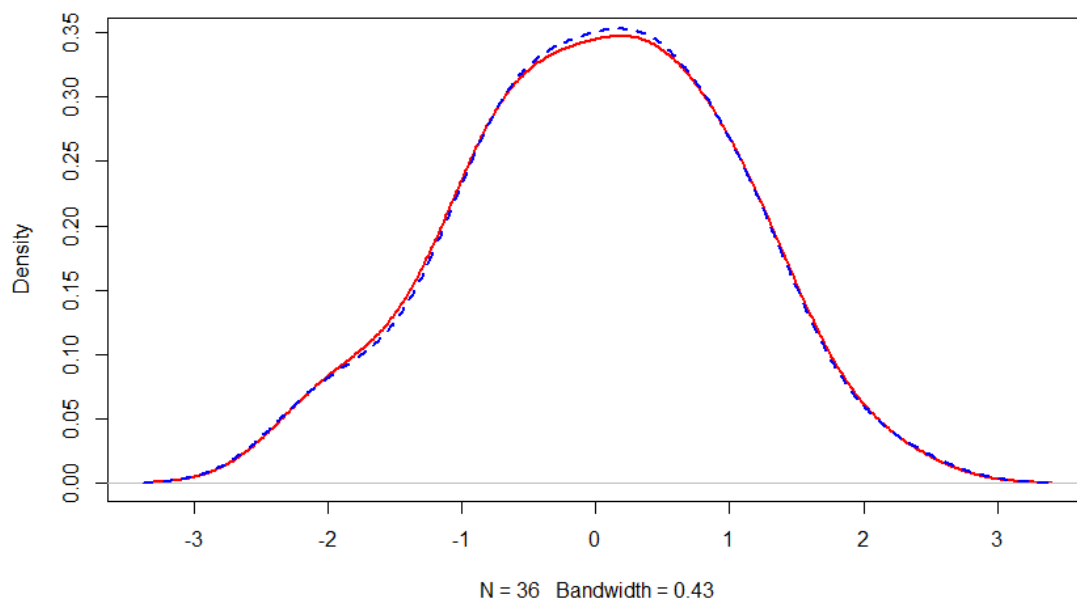


Fig 6. Density distributions of z transform of Hellinger transformed points (red) and log10 transformed points (blue).

Using the proposed transform based on Hellinger distance (5) together with z transform were obtained a new set of data. Additionally, the data was transformed using decimal logarithm and followed by z transform and were obtained a second set of transformed data.

Figure 6 contains the density distributions of Hellinger transform and decimal logarithm transform. It shows an equivalence of those transforms.

## Conclusions

Ignition probability variations induced by the presence of moisture was a good process for generating new experimental data population.

Clustering process based on Hellinger distance ensure the stability of results.

For exponentially distributed values, based on Hellinger distance was proposed a new transform which is equivalent with logarithm transform.

The proposed Hellinger transform open new way for comparisons even for data sets which do not obey to a specific density distribution.

## Acknowledgements

This paper contains a summary of the researches regarding the determination of the humidity influence of the air used in the test mixtures of 8.3% air + methane on the sensitivity to ignition. Tests and preliminary statistical analysis were performed inside the national project "Study of the test mixture humidity influence over the sensitivity of the spark test apparatus" National Research Program no.45N / 31.01.2007-2015. This paper was developed within a Research Program - Nucleu Program 2018, project PN 18 17 02 01 – "Researches for developing the assessment and testing of technical equipment designed for use in areas with hazard of explosion and of personal protective equipment".

For performing the calculus and diagrams were used the R language and R Studio environment (R Development Core Team R, 2008), (R Core Team R, 2015).

## References

- Cioclea D., Găman, A.G., Gherghe, I., Rădoi, F., Boantă, C., Păsculescu, V., *Possibilities to priorly establish the structures of ventilation networks affected by underground explosions*, The 24<sup>th</sup> International Mining Congress and Exhibition of Turkey, 14 – 17 April 2015, Antalya, Turcia, ISBN 978-605-01-0705-0, Pag. 991-997, (2015)
- Darie M., Ionescu J., Burian S., Csaszar T., Moldovan L., *Ignition probability assessment of low current circuits designed for use in explosive atmospheres*, Environmental Engineering and Management Journal, volume 11/2012, No.5, (2012)
- IEC Standard 60079-11, - *Explosive atmospheres -- Part 11: Equipment protection by intrinsic safety "i"*, (2012)
- Johansmeyer U., *Investigations into the Intrinsic Safety of field bus systems*, PTB-Bericht, (1994)
- R Core Team R: *A language and environment for statistical computing*, R Foundation for Statistical Computing, Vienna, Austria. URL <http://www.R-project.org/>, (2015)
- R Development Core Team R: *A language and environment for statistical computing*. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL <http://www.R-project.org>, (2008)
- Wikipedia, *Hellinger distance*, available [https://en.wikipedia.org/wiki/Hellinger\\_distance](https://en.wikipedia.org/wiki/Hellinger_distance), 10.08.2018, (2018)

## Determination of danger, risk and fire vulnerability parameters. Numerical simulation in fire extinction

Cristian Tomescu<sup>1</sup>, Doru Cioclea<sup>1</sup>, Ion Gherghe<sup>\*</sup>, Emeric Chiuzean<sup>1</sup>, Marius Morar

<sup>1</sup>National Institute for Research and Development in Mine Safety and Protection to Explosion – INSEMEX,  
32-34 G-ral Vasile Milea Street, Petroșani, Hunedoara, Romania

---

### Abstract

The specialized literature deals with the phenomenology of fires in the industrial and civilian area, as well as with protection against fire, as a very complex problem in order to give a specialized response to such an emergency situation.

INCD-INSEMEX Petroșani, in his fire and explosion portfolio, owns numerous research expertise based on the causes that generated such events, in which it succeeded to elucidate these causes by analysing the situations, states and circumstances and reporting them to the mechanism of the phenomenon initiation, development and propagation.

The numerical analysis software using the ANSYS-based CFD solution - a finite element analysis software package widely used in industry and research, is the tool that renders the image of a fire or explosion event. But in most cases, this computerized program was used to identify causes and not to prevent fires.

Thus, the present paper proposes an analysis of the fire risk parameters and the numerical simulation of a selection of fire-extinguishing systems.

**Keywords:** fire, danger, risk, vulnerability, simulation.

### 1. Introduction

Fire prevention activities are a set of technical and organizational measures, as well as specific actions planned and executed according to the legislation, in order to prevent, reduce or eliminate the risks of fires and their consequences, the protection of persons, material goods and the environment through specific means and measures.

Fire risk is the performance criterion that represents the overall probability of a fire outbreak determined by the interaction of the properties of specific materials and combustible substances with potential ignition sources under certain circumstances at the same time and space. It cannot be analysed and treated in the study of combustion without elements vulnerable to fire: humans, buildings and the environment.

### 2. The parameters for harmful risk assessment

In industrial facilities, institutions, residential buildings, technological installations and times where materials and combustibles are stored, handled and used, there is a fire hazard. This is due to the fact that the materials and substances have stored a certain caloric potential (thermal load). If a source of ignition is in the same space or surroundings, the danger of fire is imminent. It occurs when there is a correlation in time and space of specific conditions. (Balulescu, P., Macris, V., 1979)

In practice, it is necessary to appreciate as accurately as possible the fire hazard in order to take the most effective preventive measures, which have as main purpose:

- keeping the probability of a fire out to a low level;
- stopping the fast propagation of a possible fire or limiting it to minimal damage.

The force of destruction of a fire acts in two directions: on the building and on its contents. The building ruins consist of the destruction of the building elements. The degree of destruction is determined by two factors acting in the opposite direction: the intensity and duration of the fire on the one hand and the resistance of the construction on the other.

---

<sup>\*</sup> Corresponding author: Cristian Tomescu  
E-mail: cristian.tomescu@insemex.ro; Phone: + 40 254541621; Fax: +40 254546277

For determining the potential fire risk, the following factors will be taken into account:

- thermal load;
- visibility conditions and the possibility of increased damage due to smoke releases;
- the size of fire compartments according to the possibility of evacuation of the building and ventilation of the rooms;
- the height of the room or building;
- the possibility of increased damage due to the release of corrosive combustion gases;
- agglomeration of values (materials) per unit area.

Fire risk factors for buildings and people, as well as the amount of damage caused by fire, smoke, corrosive combustion gases, etc. must be determined by using risk factors.

The calculation of the fire hazards must take into account two main factors:

- thermal load calculated in a certain manner;
- fire resistance of buildings, assessed and interpreted with all the implications.

Thermal load  $S_Q$  is the first and most important parameter of fire risk. It represents the amount of heat that can be released by the complete combustion of all the combustible, fixed and mobile materials present in the space affected by the fire. There are several calculation formulas according to the standard used and updated. The general formula for calculating the heat load is given by:

$$S_Q = \sum Q_i \times M_i \quad [\text{MJ}] \quad (1)$$

$M$  - the mass of combustible materials of the same kind in the space considered in Kg;

$Q$  - lower calorific value for an MJ / kg or MJ / m<sup>3</sup> gas.

The thermal load density is determined by the ratio of the thermal load to the surface of the fire-affected space (the surface of the fire compartment) according to the following equation:

$$q = \frac{S_Q}{A} \quad (2)$$

$S_Q$  - total thermal load in MJ

$A$  - The area of the room, the fire compartment in m<sup>2</sup>

The amount of heat that is thought to act upon the building elements ( $S_A$ ) is determined by the relationship:

$$S_A = c \cdot p \cdot \sum_{i=1} m_{Q_i} M_i' \quad [\text{MJ}] \quad (3)$$

in which:

$c$  - Coefficient which takes into account the size of the geometric dimensions of the space considered;

$p$  - Coefficient which takes into account the number of levels and the conditions of ventilation and dissipation of heat;

$m$  - coefficient to account for the combustion capacity of the materials under fire conditions;

$Q_i$  - lower calorific power (defined above);

$M$  - the amount of combustible materials of the same type in MJ;

The values of the coefficients  $c$ ,  $p$  and  $m$  are found in the default tables.

Fire resistance of building elements is a precise and measurable notion, but calculations are obtained due to research and experimental results in the field, based on analytical and alternative methods for verifying the fire resistance of incandescent structures. The minimum fire resistance of the main building elements in the structure of the building is specified in specific technical regulations.

The assessment of the fire hazard of combustible substances and materials is likely to be performed only if a number of parameters are known, such as:

- *Fuel group* - the property that some bodies have to burn in the presence of oxygen or air;
- *Fuel index* - dimensional size, expressing the ratio between the amount of heat released by the burning material and the amount of thermal energy of the ignition source;
- *Ignition temperature* - the minimum temperature at which the vapours of a combustible liquid form with the air above it a mixture of a certain concentration that ignites it in contact with a source of ignition (flame, incandescent, sparks, mechanical sparks etc.);
- *Ignition temperature* - the lowest temperature at which a substance in the presence of air or oxygen is to be heated to ignite and continue to burn on its own without further heating;
- *Self-ignition temperature* - the minimum temperature to which it is necessary to heat a combustible substance to produce ignition of the vapor-air mixture without coming in direct contact with a source of ignition;
- *Self-ignition tendency* - a phenomenon found in a number of combustible substances and materials that are first subjected to self-heating as a result of chemical or biological processes in the mass of organic substances themselves;
- *Explosion limits (minimum and maximum)* - combustion vapours and gases may form explosive mixtures with air which ignite only if they have a certain concentration;

- *Vapour ignition limits* - minimum magnitude of the energy of an electrical or mechanical spark sufficient to ignite a gas-air, vapour-air or air-to-light mixture at a certain concentration (the one that ignites more easily);
- *Minimum fire-extinguishing concentration* - the minimum oxygen concentration in the air mixture, where a diluent is introduced under which it is not possible to inflate their mixtures with gases, vapours, or combustible dusts, and thus the propagation of combustion in the whole volume;
- *Minimum oxygen content for the explosion* - the oxygen content of the environment in which a combustible material continues to burn without being subjected to the action of the ignition source;
- *Burning rate* - the amount of fuel consumed by combustion in the unit of time;
- *Liquid heating rate* - determined by the rate of increase of the thickness of the liquid layer, if it burns on a free surface, the temperature of which is equal to the boiling temperature of the liquid;
- *The maximum explosion pressure* - the maximum explosion pressure that would occur if there was no heat exchange between the combustion products and the walls of the plant can be calculated by knowing the concentration, composition of the respective substances, the initial state of the system, and the quality of volatile substances (dusts);
- *Most suitable extinguishing agent* - for each material and fuel substance, the most effective extinguishing agent should be established.

### 3. Numerical simulation of fire extinguishing

Three main categories are known as fire protection elements:

- passive fire protection, specialized building elements and materials for the protection against fire;
- active protection, automatic signalling and fire-extinguishing systems;
- passive-active protection, manually operated intervention means.

#### 3.1. Fire extinguishing systems

The system of active fire protection or active fire control is also provided by equipping buildings, technological installations and fire extinguishing installations: external and internal hydrants, sprinkler systems, drenched installations as well as sprinkler systems, foam, powders and inert gases. The most widespread fire-extinguishing systems are those with water. The paper is dealing with sprinkler systems.

Sprinkler systems are automatic fire detection, signalling and fire-extinguishing systems, automatically operating when the ambient temperature due to fire exceeds the set limits. The system uses dispersed water as a spraying agent in the form of droplets made with sprinklers. It automatically switches to heat when the thermal fuse (set to approximately 30 ° C above the normal ambient temperature) reaches the activation temperature, the sprinkler head opens, the water drops in the form of drops. Only those sprinkler heads that are above or near the source of the fire are opened, those whose operation is required for the fire-fighting operation. Types of sprinkler extinguishing systems: in water-water system, in water-air system and in mixed system.

#### 3.2. Considerations on Computational Fluid Dynamics (CFD).

CFD - Computational Fluid Dynamics is a model of fluorescence dynamics in the ANSYS program, more focused on the virtualization of fluid flow in fire-affected environments, based on Navier-Stokes equations suitable for low speed, thermal fluxes, focusing on transport of heat and smoke. Partial derivatives of mass, torque and energy conservation equations are approximated as finite differences, and the solution is continuously updated over a three-dimensional network. Thermal radiation is calculated by finite volume technique on the same fluid flow network. To simulate smoke movement, spraying water or fuel injection, Lagrange particles are used.

#### 3.3. Geometry creation

To perform the simulation, a spray head model for water fog extinguishing installations was used, mounted vertically with the deflector down. This cutting head was drawn in the ANSYS program using the actual dimensions (Fig.1). (Dumitru, L., Serban, M., et al. 2015)

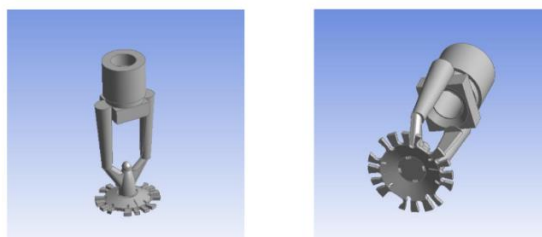


Fig. 1 – Geometry of the chosen sprinkler model

### 3.4. Dividing into finite elements (MESH)

Taking into account that a computer can only perform simple mathematical operations, it must be brought into an algebraic form appropriate for programming. This transformation is known as the discretization of equations. The stability of the numerical calculation of the meshing equations cannot be predicted analytically, it is demonstrated in practice. This stability is being tested, especially in the area of discontinuities. Both Euler's equations and the Navier-Stokes equations admit discontinuities. (Lupu C., Vlasin N., et al.2015)

Once the shape of the field of analysis has been determined, it must be meshed (Figure 2). The sprinkler meshing was 0.1 mm, 1 cm outboard, and 1 dm room walls.

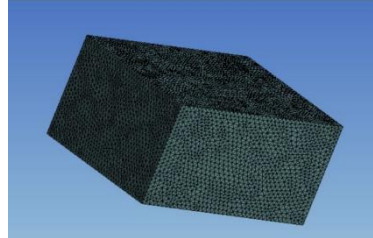


Fig. 2 – Dividing into finite elements

Number of finite elements that make up the entire domain analysed is presented in Table 1:

Table no. 1.

Units	Fields	Elements
Default Domain	862734	3378320

### 3.5. Boundary conditions (SETUP)

The boundary conditions in the simulation are as follows:

- Type of analysis - 180 s simulation run time is selected;
- the scope includes the entire assembly of components, in this option the air and water particles (particles forming the fluid jet) are defined, the particles used are small particles with a diameter of 400 microns, average particles with a diameter of 600 microns and particles large diameters of 900 microns;
- inlet - subsonic flow at 2.6 m / s, 3 types of particles having equal velocity and a temperature of 25<sup>0</sup> C;
- outbreak - is an area of 1 m<sup>2</sup>, to which a temperature of 400<sup>0</sup> C with a radiation of 8,000 W is applied;
- walls (without friction, the particles are perpendicular to the floor);
- the floor having a temperature of 25 ° C;
- the height of the sprinklers is 2.2 m;
- sprinkler - all parts of the spray head are defined.

### 3.6. Solving equations (Solutions)

At this stage, the program performs the calculations without user intervention based on the boundary conditions imposed in the previous step. It is the only step that runs without user intervention.

Figure no.3 illustrates the graph of solutions imposed by the boundary conditions.

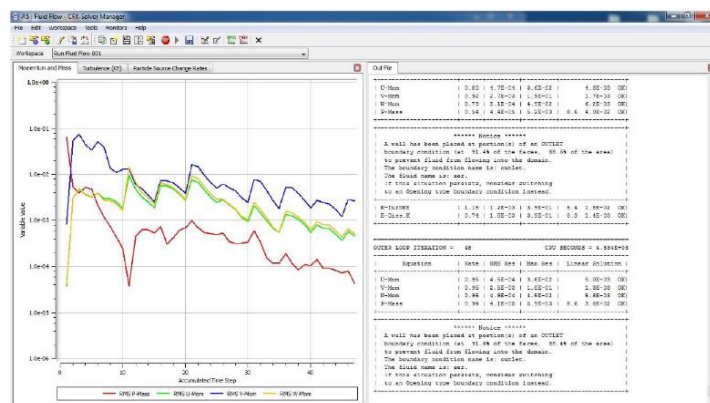


Fig. 3 – Solving equations in the ANSYS software

### 3.7. Results

The results are displayed following the mathematical calculations presented in the previous stage. This step is very important because it helps to interpret the results according to the chosen parameter. It has been chosen to plan a vertical plane through the focal axis of the furnace.

In Figure no. 4 a) a high temperature is observed in almost all of this room being around the furnace of about  $400^{\circ}\text{C}$ . In figure no. 4 b), c), it is noticed that the room temperature started to drop, the temperature in the furnace decreased by approx.  $100^{\circ}\text{C}$ . In figure no. 5 - a), b), c), the fire involution is observed within 60 seconds and after, until extinguished. After the fire was cleared, the temperature in the fired area reached almost the same value as the ambient temperature except the furnace.

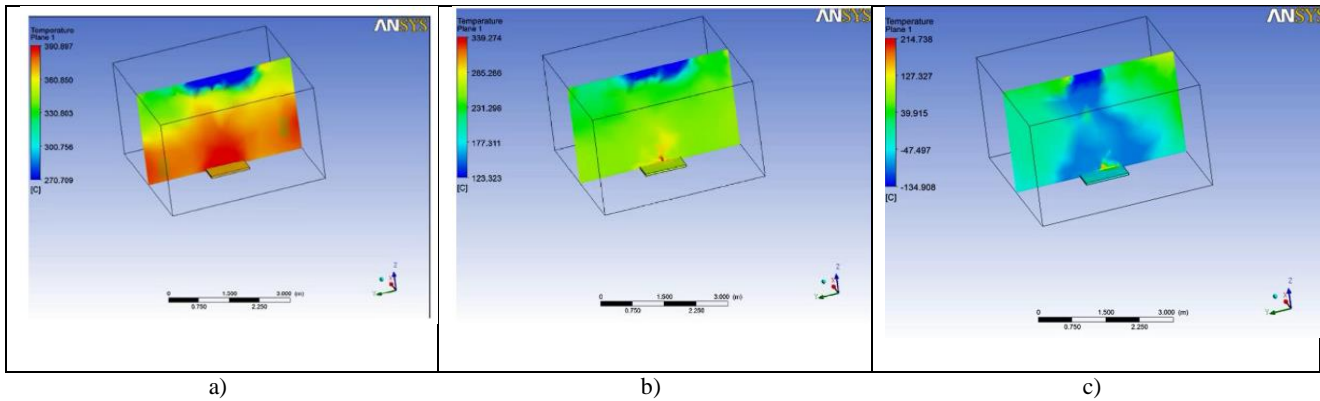


Fig. 4. a) - Section with a vertical plane after 5 seconds from the sprinkler triggering;  
b) - Section with a vertical plane in the area of the furnace after 15 seconds from the sprinkler triggering;  
c) - Section with a vertical plane after 25 seconds from sprinkler triggering.

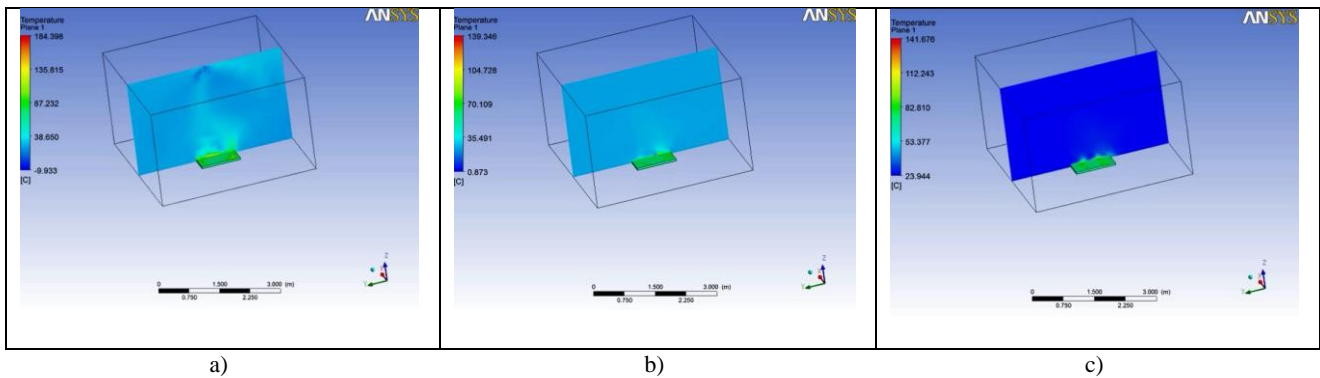


Fig. 5. a) - Section with a vertical plane after 40 seconds from the sprinkler triggering  
b) - A section with a vertical plane after 50 seconds from the sprinkler triggering  
c) extinguished fire

Figure no. 6 shows the variation of the internal temperature at a height above the furnace over a period of 0 to 180 s. The air temperature in the room after 30 s is approximately  $240^{\circ}\text{C}$  and at the top of the room it is much slower. It can be noticed that at  $t = 60$  s there is a sudden increase in the temperature at the ceiling due to the fact that the contact of the water particles with the furnace takes place a sudden evaporation of them by transporting some of the heat of the furnace to the ceiling. The simulation shows that it is sufficient to operate the sprinkler for 300 seconds to complete the fire extinguishing.

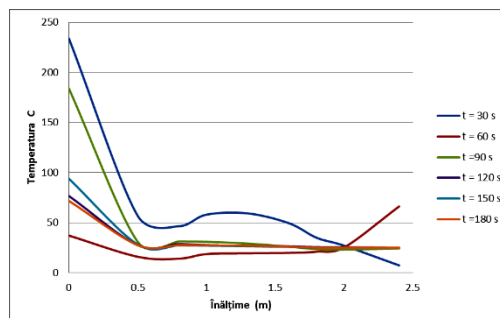


Fig. 6 – Temperature variation over the furnace



#### **4. Conclusions**

1. For the assessment of fire risk in fire prevention, it is necessary to analyse a matrix of parameters that characterize a fire and the results of this analysis lead to the low probability of a fire outbreak, as well as to the stop of the rapid propagation of a possible fire or to minimal damage.
2. In practice, it is important to choose, depending on the types of protected material, but also the likely types of fire detection, fire extinguishing systems, fire detection, signalling and fire extinguishing, automatically entering into operation when the ambient temperature due to fire exceeds the established limits.
3. The sprinkler extinguishing system uses water as a water scavenger, dispersed as fine water drops, which performs a heat exchange with the energy produced in the combustion zone, preventing the temperature from rising. This energy exchange is proportional to the surface covered by water droplets, not their volume. At an equal volume, the smaller the droplets, the higher the area on which the energy exchange takes place. The secondary effect is the decrease in oxygen concentration.
4. ANSYS computational simulation software for phenomena occurring in spaces where fires can occur, includes information about the network that defines the geometry, environment, solid body geometry, material properties, combustion kinetics, and desired output data. The numerical network consists of several cells of uniformity, with which all the geometric features of the bodies in the scenario must comply.
5. By numerical simulation of the Sprinkler fire extinguishing system, with the CFD model, a fire extinction was obtained during 5 minutes in a room whose ignited materials developed a temperature of 240<sup>0</sup> C.
6. Fire risk assessment and the use of computational simulations is a proper tool for designers and economic and non-economic agents in establishing the fire risk scenario as well as for reaching and increased safety factor for humans, materials and for environmental safety.

#### **Acknowledgements**

This paper was developed within the Nucleu-Programme, carried out with the support of MCI, project no.PN 18170202

#### **References**

- Bălulescu, P., Macris, V., *Prevenirea incendiilor* (in Romanian), Technical Publishing House Bucharest, Romania, 1979, pp 6-12
- Dumitru, L., Serban, M., ș.a. - Using numerical simulation as a method for selecting fire stone systems (in Romanian), *The fire brigade*, No. 1/2015, Publishing House Ministry of Interior, Romania, pp 180-185.
- Lupu C., Vlasin N., Tomescu C., s.a., *Computational Simulation of Fire development inside a trade Centre, Management System in Production Engineering*, Scientific and Tehnical Quarterly, no. 3/2015, ISSN 2299-0461, pp. 142-146
- [http://www.ansys.com/Support/Training%20Center/Courses/Introduction%20to%20ANSYS%20CFX-Computational Fluid Dynamics](http://www.ansys.com/Support/Training%20Center/Courses/Introduction%20to%20ANSYS%20CFX-Computational%20Fluid%20Dynamics).
- Normative on fire safety of buildings, Part II, Extinguishing installations, indicative P118/2-2013.



## Research on establishing the physical effort of rescuers according to the activity performed and type of respiration protection equipment

Andrei-Lucian Gireadă<sup>1\*</sup>, George Artur Găman<sup>1</sup>, Cristian Nicolescu<sup>1</sup>, Cosmin Ilie<sup>1</sup>,  
Alin Irimia<sup>1</sup>, Izabella Kovacs<sup>1</sup>

<sup>1</sup>National Institute for Research and Development in Mine Safety and Protection to Explosion – INSEMEX Petroșani,  
32-34 G-ral Vasile Milea Street, Postcode: 332047, Petroșani, Hunedoara County, Romania

---

### Abstract

Fatigue is a body defensive measure, limiting the intensity and volume of effort. The intensity and volume of effort can be maintained at a high level only if the body's adaptability allows it.

Measurement of fatigue is performed by measuring pulse and respiratory rate.

The decisive factor in ensuring the success of an intervention and rescue operation in toxically or chemically aggressive environments resides in the optimal and efficient design of a training process for intervention personnel, correlated, amongst other things, with the evolution of pulse and oxygen saturation, which need to be monitored through an integrated system.

Pulse is a physiological parameter commonly used in telemonitoring as it allows assessment of the rescuer's general condition, heart rhythm disturbances being recorded promptly and variations being easily differentiated between abnormal / normal. The parameter provides indications of cardiovascular function. Pulse sampling is performed automatically using devices that frequently use photometric plethysmography at the level of peripheral arteries as a measuring method.

Blood oxygen saturation (SpO<sub>2</sub>) is a global indicator of blood oxygenation (the amount of oxygen bound to haemoglobin in arterial blood), being used in cardiovascular and respiratory monitoring.

Within the paper, change in heart rate and blood oxygen saturation will be monitored, so as to determine the physical exertion of rescuers, using closed-circuit breathing apparatuses, as well as open-circuit breathing apparatuses, in confined spaces, ergometers, treadmill and ladders on different degrees of temperature and humidity.

**Keywords:** rescuer, pulse, blood oxygen saturation, training facility, monitoring, breathing apparatus

---

### 1. Introduction

Effort is the result of multiple demands (muscular, cardiorespiratory, psychic, etc.) to which the human body, (Drager, 2010) is subjected while performing different activities, (Gireadă et al, 2017).

From a biological point of view, physical effort is an appropriate biological stimulus (excitant) that forces the body to respond by electrical, mechanical, thermal manifestations. This stimulus, when properly dosed and administered to individual's particularities, leads to quantitative and qualitative accumulations aimed at achieving maximum performance, (Rotariu, 2010).

The activity of body's organs, apparatuses and systems takes place concurrently with the intensification of the body's vegetative functions, (Pupăzan et al, 2012). The greatest demands during effort are supported by systems involved in the increased supply, transport and consumption of oxygen by active tissues, (Pupăzan et al, 2015).

Increased need for oxygen and energy means within physical effort is achieved by alterations in cardiovascular parameters, that can be: immediate (acute) alterations are installed for all types of exercise, (Pupăzan et al, 2012) and during recovery and late (training) alterations, which are the result of the systematic practice of physical education and sports, for a longer period of time, (Mesina, 2013).

During effort, body adaptation is assured on one hand by nervous regulation and on the other by neuro-hormonal regulation, (Ilie et al, 2015). During exercise, a series of changes in body apparatus and systems occur, as an expression

---

\* Corresponding author. Tel.: +40 254 541 621; fax: +40 254 546277.

E-mail address: andrei.gireada@insemex.ro.

of the functional adaptation tendency, changes most apparent in the cardio-vascular system activity, (Mesina, 2013). The most obvious adaptation of this apparatus is the acceleration of heart rate, increased heart rate, which reflects the heart rhythm. Heart rhythm may reach 60 to 70 beats per minute, 120 to 150 or even 200 beats per minute in extraordinary cases at very great effort, (Pupăzan et al, 2015).

Heart rate adaptation begins immediately after initiation of effort, first with an increase over need and then a stabilization at a constant level if the effort is also constant, (Gireadă et al, 2017). After the effort ends, return to normal is made in two stages: first by a sudden drop in the beginning, then by a slow and progressive sometimes wavy decline, (Rotariu, 2010).

Another manifestation of circulatory changes during exercise is the increase in blood pressure, which is proportional to effort intensity, in this situation, both the maximum and the minimum being of interest, (Ilie et al, 2015). After the training ends, pressure returns to normal, a rebound depending on effort intensity and fitness of the trainee. In the first few minutes, pressure values fall below the resting value, then rise to normal, (Ilie et al, 2016). In the event of inappropriate adaptation of the cardio-vascular apparatus, the maximum pressure decreases abruptly before the end of the effort test, so the heart is at the limit of its resources, (Pupăzan et al, 2012).

## **2. Types of breathing apparatuses**

Respiratory protection devices are divided into:

- closed circuit respiratory devices type MEDI 17128 and DRAGER BG4, compressed oxygen-based devices, which have an autonomy of up to 4 hours depending on type and size of the filter cartridge which also has the role of regenerating breathing air. These two types of apparatus are most often used in underground industry due to their high operating time, (Ilie et al, 2015);
- open circuit respiratory devices type DRAGER PA 90, DRAGER PSS 7000, PROSALV 2000, PROSALV FIRE PLUS and PROSALV ARIAC D "DIABLO" compressed air-based devices, without regeneration of exhaled air. These devices have an autonomy of up to 60 minutes at medium effort and a cylinder load at nominal pressure. These types of apparatus are most often used in surface industry because of their low operating time, (Ilie et al, 2016).

## **3. Optimizing physical effort of rescuers according to the activity performed and type of respiratory protection equipment**

In the practical training process, intervention and rescue personnel were divided into two groups: personnel operating in the underground mining industry using closed circuit breathing equipment and surface rescue personnel using open circuit respiratory protection equipment. Two teams of 3 rescuers were selected, the first team with a surface profile and the second team with underground profile.

Rescue teams performed several types of exercises with varying degrees of difficulty, workload pertain to physical being calculated for each of them.

### **3.1. Route no. 1 - surface**

Within the training facility, a team of three surface rescuers performed several types of exercises with varying degrees of difficulty using open circuit breathing equipment:

- three narrow-space circuits;
- three series of 80 ergometer pull-ups;
- five minutes of walking on the ergometer treadmill;
- ascending and descending on the metallic scale for 50 times;
- climbing and descending the shaft ladder;
- two turns of the modular circuit.



Fig. 1. Surface rescuers

For each type of exercise, workload was calculated as follows:

I. The amount of work performed for passing thru a narrow section of the gallery, with the length of 12 meters and the section of 0.54 m<sup>2</sup>, in crawling position, repeating the activity three times:

$$A_1 = 0,5 \cdot 100 \cdot 12 \cdot 3 = 1800 \text{ Kgm}$$

II. The amount of work performed for passing thru a narrow section of the gallery, with the length of 12 meters and the section of 0.9 m<sup>2</sup>, on all fours, repeating the activity three times:

$$A_2 = 0,25 \cdot 100 \cdot 12 \cdot 3 = 900 \text{ Kgm}$$

III. The amount of work performed for passing thru a narrow section of the gallery, with the length of 12 meters and the section of 1.5 m<sup>2</sup>, in bent position, repeating the activity three times:

$$A_3 = 0,125 \cdot 100 \cdot 12 \cdot 3 = 450 \text{ Kgm}$$

IV. The amount of work performed for passing thru a labyrinth type section, with the length of 40 meters, repeating the activity 3 times:

$$A_4 = 0,055 \cdot 100 \cdot 40 \cdot 3 = 660 \text{ Kgm}$$

V. The amount of work performed for passing thru a reduced profile section of gallery, with the length of 3 meters and the section of 0.9 m<sup>2</sup>, on all fours, repeating the activity 3 times:

$$A_5 = 0,25 \cdot 100 \cdot 3 \cdot 3 = 225 \text{ Kgm}$$

VI. The amount of work performed for passing thru a reduced profile section of gallery, with the length of 3 meters and the section of 0.54 m<sup>2</sup>, in crawling position, repeating the activity 3 times:

$$A_6 = 0,5 \cdot 100 \cdot 3 \cdot 3 = 450 \text{ Kgm}$$

VII. The amount of work performed for climbing and descending a 3 meters high ladder at an angle of 90°, repeating the activity 2 times:

$$A_7 = 0,25 \cdot 100 \cdot 6 \cdot 3 = 450 \text{ Kgm}$$

VIII. The amount of work performed for lifting a weight of 20 kg at the ergometer, at a height of 1.2 m, two series of 30 repetitions each:

$$A_8 = 20 \cdot 1,2 \cdot 30 \cdot 2 = 1440 \text{ Kgm}$$

IX. The amount of work performed for climbing and descending a 9 meters high ladder at an angle of 90°, repeating the activity 2 times:

$$A_9 = 0,35 \cdot 100 \cdot 18 \cdot 2 = 1260 \text{ Kgm}$$

X. The amount of work performed for passing thru a normal (horizontal) profile working, on the ergometric treadmill at a speed of 5 km/h for 5 minutes:

$$A_{10} = 0,055 \cdot 100 \cdot 400 = 2200 \text{ Kgm}$$

XI. The amount of work performed for passing thru a working, by climbing and descending a 5 steps ladder, at an angle of 45°, repeating the activity 40 times:

$$A_{11} = 0,25 \cdot 100 \cdot 80 = 2000 \text{ Kgm}$$

XII. The amount of work performed for passing thru a reduced profile section of gallery, with the length of 6 meters and the section of 0.6 m<sup>2</sup>, in crawling position, repeating the activity 2 times:

$$A_{12} = 0,5 \cdot 100 \cdot 6 \cdot 2 = 600 \text{ Kgm}$$

XIII. The amount of work performed for passing thru a reduced profile section of gallery, with the length of 41 meters and the section of 0.9 m<sup>2</sup>, on all fours, repeating the activity 2 times:

$$A_{13} = 0,25 \cdot 100 \cdot 41 \cdot 2 = 2050 \text{ Kgm}$$

XIV. The amount of work performed for passing thru a labyrinth type section, with the length of 36 meters, repeating the activity 3 times:

$$A_{14} = 0,055 \cdot 100 \cdot 36 \cdot 3 = 594 \text{ Kgm}$$

XV. The amount of work performed for climbing and descending two 3 meters high ladders at an angle of 90°, repeating the activity 2 times:

$$A_{15} = 0,35 \cdot 100 \cdot 6 \cdot 2 = 420 \text{ Kgm}$$

Total amount of work performed is:

$$A = \sum A_1 \div A_{15} = 1800 + 900 + 450 + 660 + 225 + 450 + 450 + 1440 + 1260 + 2200 + 2000 + 600 + 2050 + 594 + 420 = 15.499 \text{ Kgm}$$

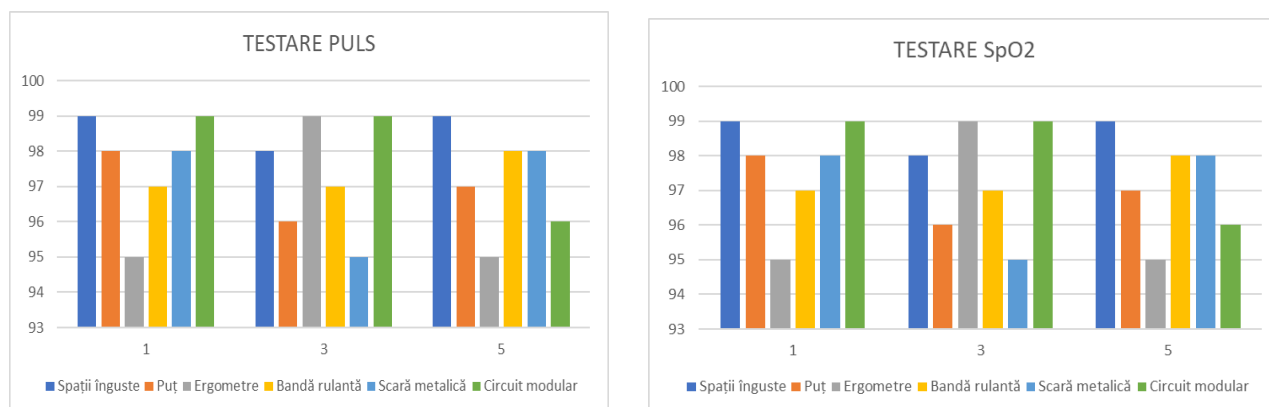
The total amount of work performed by a surface rescuer in training for passing thru the first training route was 15,499 Kgm.

Measurements of blood oxygen saturation and pulse of each rescuer were also performed, repeating the measurements after the end of each activity.

For this route, oxygen blood saturation and pulse are shown in table no. 1 and graphically in figure 2.

Table 1 – route no. 1 - surface

No.	GROUP 1 INSTRUCTION	Subject 1		Subject 2		Subject 3	
		Pulse	SpO <sub>2</sub>	Pulse	SpO <sub>2</sub>	Pulse	SpO <sub>2</sub>
1	Narrow spaces	136	99	142	98	130	99
2	Ergometers	160	98	140	96	111	97
3	Treadmill	124	95	109	99	119	95
4	Metallic ladder	147	97	110	97	122	98
5	Shaft	111	98	111	95	110	98
6	Modular circuit	121	99	126	99	133	96

Fig. 2. (a) Pulse variation for route no.1; (b) SpO<sub>2</sub> variation for route no.1

### 3.2. Route no. 2 – underground

Within the training facility, a team of three underground rescuers performed several types of exercises with varying degrees of difficulty using closed circuit breathing equipment:

- two narrow-space circuits;
- three series of 80 ergometer pull-ups;
- seven minutes of walking on the ergometer treadmill;
- ascending and descending on the metallic scale for 30 times;
- climbing and descending the shaft ladder;
- two turns of the modular circuit.



Fig. 3. Underground rescuers

For each type of exercise, workload was calculated as follows:

I. The amount of work performed for passing thru a reduced profile section of gallery, with the length of 11 meters and the section of 0.54 m<sup>2</sup>, on all fours, repeating the activity 2 times:

$$A_1 = 0,5 \cdot 100 \cdot 11 \cdot 2 = 1100 \text{ Kgm}$$

II. The amount of work performed for passing thru a reduced profile section of gallery, with the length of 12 meters and the section of 0.9 m<sup>2</sup>, in crawling position, repeating the activity 3 times:

$$A_2 = 0,25 \cdot 100 \cdot 12 \cdot 3 = 900 \text{ Kgm}$$

III. The amount of work performed for passing thru a reduced profile section of gallery, with the length of 12 meters and the section of 1.5 m<sup>2</sup>, in bent position, repeating the activity 3 times:

$$A_3 = 0,125 \cdot 100 \cdot 12 \cdot 3 = 450 \text{ Kgm}$$

IV. The amount of work performed for passing thru a labyrinth type section, with the length of 40 meters, repeating the activity 3 times:

$$A_4 = 0,055 \cdot 100 \cdot 40 \cdot 3 = 660 \text{ Kgm}$$

V. The amount of work performed for passing thru a reduced profile section of gallery, with the length of 3 meters and the section of 0.9 m<sup>2</sup>, on all fours, repeating the activity 3 times:

$$A_5 = 0,25 \cdot 100 \cdot 3 \cdot 3 = 225 \text{ Kgm}$$

VI. The amount of work performed for passing thru a reduced profile section of gallery, with the length of 3 meters and the section of 0.54 m<sup>2</sup>, in crawling position, repeating the activity 3 times:

$$A_6 = 0,5 \cdot 100 \cdot 3 \cdot 3 = 450 \text{ Kgm}$$

VII. The amount of work performed for climbing and descending a 3 meters high ladder at an angle of 90°, repeating the activity 3 times:

$$A_7 = 0,25 \cdot 100 \cdot 6 \cdot 3 = 450 \text{ Kgm}$$

VIII. The amount of work performed for lifting a weight of 20 kg at the ergometer, at a height of 1.2 m, two series of 30 repetitions each:

$$A_8 = 20 \cdot 1,2 \cdot 30 \cdot 2 = 1440 \text{ Kgm}$$

IX. The amount of work performed for climbing and descending a 1.5 meters high ladder at an angle of 90°, repeating the activity 2 times:

$$A_9 = 0,35 \cdot 100 \cdot 23 \cdot 2 = 1610 \text{ Kgm}$$

X. The amount of work performed for passing thru a normal (horizontal) profile working, on the ergometric treadmill at a speed of 5 km/h for 5 minutes:

$$A_{10} = 0,055 \cdot 100 \cdot 436 = 2401 \text{ Kgm}$$

XI. The amount of work performed for passing thru a working, by climbing and descending a 5 steps ladder, at an angle of 45°, repeating the activity 500 times:

$$A_{11} = 0,25 \cdot 100 \cdot 112 = 2800 \text{ Kgm}$$

XII. The amount of work performed for passing thru a reduced profile section of gallery, with the length of 9 meters and the section of 0.6 m<sup>2</sup>, in crawling position, repeating the activity 2 times:

$$A_{12} = 0,5 \cdot 100 \cdot 9 \cdot 2 = 900 \text{ Kgm}$$

XIII. The amount of work performed for passing thru a reduced profile section of gallery, with the length of 38 meters and the section of 0.9 m<sup>2</sup>, on all fours, repeating the activity 2 times:

$$A_{13} = 0,25 \cdot 100 \cdot 38 \cdot 2 = 1900 \text{ Kgm}$$

XIV. The amount of work performed for passing thru a labyrinth type section, with the length of 36 meters, repeating the activity 3 times:

$$A_{14} = 0,055 \cdot 100 \cdot 36 \cdot 3 = 594 \text{ Kgm}$$

XV. The amount of work performed for climbing and descending two 3 meters high ladders at an angle of 90°, repeating the activity 2 times:

$$A_{15} = 0,35 \cdot 100 \cdot 4,5 \cdot 2 = 320 \text{ Kgm}$$

Total amount of work performed is:

$$A = \sum A_1 \div A_{15} = 1100 + 900 + 450 + 660 + 225 + 450 + 450 + 1440 + 1610 + 2401 + 2800 + 900 + 1900 + 594 + 320 = 16.200 \text{ Kgm}$$

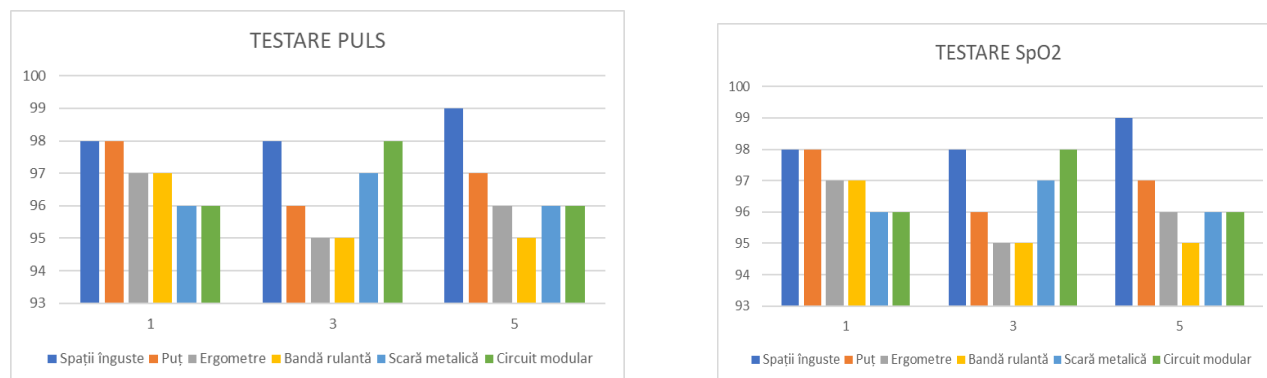
The total amount of work performed by an underground rescuer in training for passing thru the second training route was 16,200 Kgm.

Measurements of blood oxygen saturation and pulse of each rescuer were also performed, repeating the measurements after the end of each activity.

For this route, oxygen blood saturation and pulse are shown in table no. 2 and graphically in figure 4.

Table 2 – route no. 2 - underground

No.	GROUP 2 - INSTRUCTION	Subject 1		Subject 2		Subject 3	
		Pulse	SpO <sub>2</sub>	Pulse	SpO <sub>2</sub>	Pulse	SpO <sub>2</sub>
1	Narrow spaces	159	98	149	98	149	99
2	Ergometers	145	98	133	96	139	97
3	Treadmill	141	97	125	95	138	96
4	Metallic ladder	145	97	130	95	133	95
5	Shaft	135	96	136	97	126	96
6	Modular circuit	137	96	146	98	137	96

Fig. 4. (a) Pulse variation for route no.2; (b) SpO<sub>2</sub> variation for route no.2

#### 4. Conclusions

Training of rescuers in the narrow spaces training facility leads to an increase in the level of safety and health at work, by increasing the capacity for safe intervention in case of accidents, disasters, etc.

Rescue activities in toxic/ explosive/ flammable environments, either in response to incidents, simulated emergency situations or training activities, are confronted with dangerous situations. These hazards are an integral part.

When properly recognized and managed, hazards can be reduced to an acceptable level of risk. Obviously, the acceptability of a risk depends on the importance of operation's outcome, involving that risk. If people's lives are in danger, more dangerous operations are allowed, ensuring that risks are recognized and measured. This is a practical use of hazard identification and control activity.

Intervention activity under such special conditions may only be carried out by personnel trained and certified to do so, personnel using individual breathing equipment.

#### Acknowledgements

This paper was developed within the Nucleu-Programme, carried out with the support of MCI, project no. PN 18 17 02 02 (Research on improving health and safety in hazardous environments with explosive, flammable and toxic atmospheres)

#### References

- Andrei Gireadă, George A. Găman, Daniel Pupăzan, Cosmin Ilie, Alin Irimia, Sorin Burian, *Health and safety security essential requirements regarding on construction of items aimed to limit the effects of explosion*, the proceedings of the XVIIth Symposium "Young People and multidisciplinary research" ISSN 1843-6609, (2017).
- Cristian Rotariu, *Remote monitoring of vital parameters using embedded systems*, (2010).
- Cosmin Ilie, Artur George Găman, Daniel Pupăzan, Angela Călămar, Alin Irimia, Andrei Gireadă, *Study on the rescuers behaviour exposed to high temperature and humidity in the INCD INSEMEX Petroșani training facility* Occupational Health and Safety – SESAM, Proceedings of the symposium ISSN 1843-6226, (2015).
- Cosmin Ilie, George Artur Găman, Daniel Pupăzan, Alin Irimia, Andrei Gireadă, *Assessment systems for intervention and rescue personnel in toxic / explosive / flammable environments in the extractive industry*, FOCUS Publishing House, ISBN 978-973-677-314- 3, (2016).
- Drager, *Technical leaflet, Pulse monitoring system*, ELGO, Germany, (2010).
- Daniel Pupăzan, Găman G.A., Ilie C., *Information system for simulation and assessment of rescuers interventions in toxic, explosive and flammable environments*, Environmental Engineering and Management Journal, 11, 1337 – 1342, (2012).
- Daniel Pupăzan, Artur George Găman, Cosmin Ilie, Angela Călămar, Alin Irimia, Andrei Gireadă, *Research on designing a facility for rescuer's testing and training in confined spaces*, Occupational Health and Safety - SESAM Proceedings of the symposium ISSN 1843-6226, (2015).
- Victor Mesina, *Methods of research and evaluation of the state of functioning of the human body during work with physical effort*, (2013).



## Testing the temperature proof of self-contained breathing apparatus, based on compressed air

Alin Irimia\*, Sorin Burian, Florin Păun, Dan Gabor, Marius Darie

National Institute for Research and Development in Mine Safety and Protection to Explosion – INSEMEX Petroșani,  
32-34 G-ral Vasile Milea Street, Postcode: 332047, Petroșani, Hunedoara County, Romania

---

### Abstract

Compressed air breathing apparatuses have the widest range within industrial activities and are subject to intense demands from the work environment. During interventions, the apparatus may be subjected to flames or high temperatures. To meet these demands, insulating appliances are inspected, during test stage, for high temperature exposure with the use of a test stall. The components of the stall are the dummy carrier of the test apparatus, its transport carriage, the preheating furnace and the burner battery. Testing an insulating apparatus at high temperatures involves checking the integrity of the device after exposure to flames and checking functional parameters with a breathing machine after the exposure flame has ended. The insulating device is exposed to flames of a burner battery for 15 seconds, after which the breathing apparatus is subject to a free fall. The materials of the apparatus must not allow the persistence of flames nor damage after exposure to flames.

The paper presents the approach to carrying out the stall for high temperature testing of compressed air insulating devices.

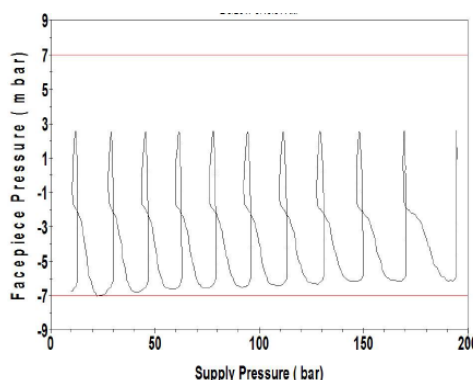
*Keywords:* temperature proof, insulating apparatus, stall, flame, furnace

---

### 1. Introduction

Compressed-air self-contained breathing apparatuses should be capable of functioning without disturbance when exposed to temperatures between -30° C and 60° C. Temperature proof of appliances involves the use of materials that don't allow the persistence of flames for more than 5 seconds after the flame has been removed from the exposed surface. Hoses used in insulating appliances as well as materials from which valves are made must not allow flame propagation. From a mechanical point of view, the apparatuses subjected to the high temperature test must remain sealed, the air supply must operate even if there are deformations of the components. (Ilie et al, 2015)

Prior to exposing the device to high temperature, a functional parameter check of the insulator is performed by means of the breathing machine. The breathing machine is set at 25 cycles / minute with a volume of circulating air of 2 liters / cycle. During the test, a mask pressure graph and an outline of the minimum and maximum pressure values in the mask are obtained. A print screen of a test performed with the use of a breathing machine is shown in figure 1.



---

\* Corresponding author. Phone: +40 254 541 621; Fax: +40 254 546277  
E-mail address: alin.irimia@insemex.ro

Fig. 1. Print screen of testing the breathing resistance of an insulating device

The breathing machine also tests the tightness of the high-pressure circuit, opening of the safety valve, accurate display of the cylinder pressure on the pressure gauge and the mask tightness, values highlighted in the print screen shown in figure 2 (Ilie et al., 2017).

<b>Pressure Gauge Test :</b>		<b>Pass</b>	
<b>70 bar :</b>	<b>100 bar :</b>	<b>150 bar :</b>	
Pass 74.7	Pass 105.4	Pass 154.	
<b>Alarm Accuracy :</b>		Pass 55.	bar
<b>Static Facepiece Pressure :</b>		Pass 0.0	mbar
<b>Bypass Test :</b>		Pass 6	L/min
<b>High Pressure Leakage :</b>		Pass 0.8	bar
<b>Safety Valve Opening Pr.</b>		Pass 12.	bar

Fig. 2. Print screen of testing the essential parameters of insulating devices with the breathing machine

## 2. The test bench

Before being tested, the insulator with both the cylinder and mask is conditioned at 60° C and a relative humidity of 50% for 4 hours. During conditioning, the filling pressure of the cylinder will be 100 bar and in the case of cylinders made of composite materials, the conditioning time will be 12 hours. After conditioning, the insulator, along with the mask and cylinder, will be fitted on a dummy. The dummy will be equipped with a flame proof jacket, to be used for up to three flame exposures. The dummy is made of hardwood, of several mechanically joined elements, their dimensions being shown in figure 3.

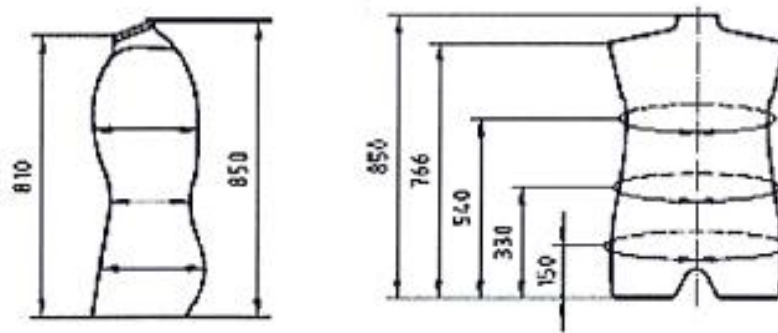


Fig. 3. Dummy dimensions

On the centre pivot, the dummy will be provided with a channel to connect the Sheffield fake head to the breathing machine. Both the dummy and the breathing machine will be placed on the transport carrier, which will be effected by overlapping two platforms, the lower one will provide the space needed for the breathing machine, while the dummy will be fitted on the upper platform. The upper platform shall be equipped with a mechanism allowing the dummy to free fall on a distance of 150 mm. As the upper part of the carrier will be exposed to high temperatures and the breathing machine will be placed on the lower part, between the two floors there must be a bridging made of flame proof heat insulating material. The transport carrier shall be equipped with four wheels positioned on two axes to allow movement along the tread to the preheating furnace and e burner bank (SR EN 137\_2008)

The preheating furnace has the purpose of providing a homogeneous temperature of 90°C around the dummy. The heating is done through air circulation, the heat source power must be chosen so as to allow the return to test temperature within 60 seconds from the moment that the dummy was put in.

Figure 4 shows the positioning of the dummy in the preheating furnace and the isolation of the carrier's lower level from the inside of the furnace.



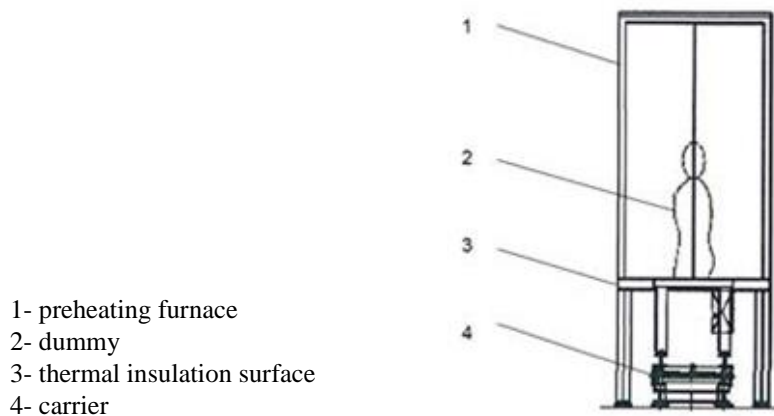


Fig. 4. Dummy's carrier inserted into the furnace

After 15 minutes of exposure to 90° C in the furnace, the dummy is transported with the carrier to the centre of the burner. This is made in the form of two burner batteries composed of four lines of linear burners spaced at 190 mm from each other, in front of and behind the dummy, each having 900 mm in length. The fuel used is propane of at least 99.5% vol. injected along with air. In order to reach a temperature of 90-100°C measured at 250 mm of the burner, an optimal air and gas mixture must be achieved in dynamic mode, propane being injected at a pressure of 1.5 bar through a nozzle of 4.5 mm and the compressed air at 5 bar through a 6 mm nozzle. The ignition system must ensure simultaneous ignition of the burner batteries and insertion of the dummy in between the burners must occur no more than 30 seconds after leaving the furnace. Details on making the burner battery are shown in figure 5.

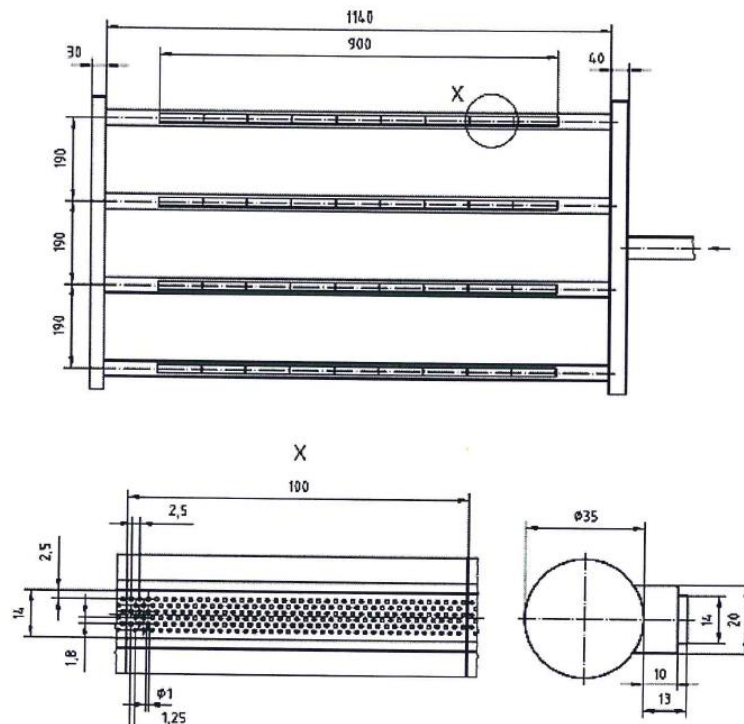
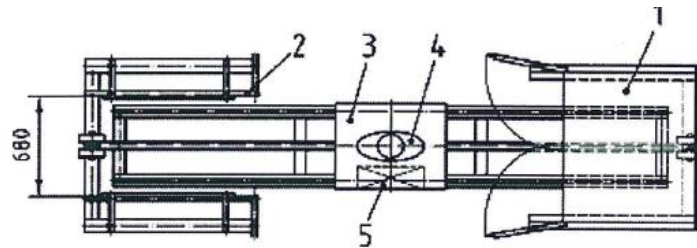


Fig. 5. Details on making the burner battery

After a 10-second exposure to flame, the possible persistence of fire on the device components is monitored to establish if the appliance meets the flame proof conditions. The apparatus is then subjected to a mechanical shock by releasing the locking mechanism of the upper platform on which the dummy is fitted and by free fall thereof at a height of 150 mm. Figure 6 shows a top view of the test bench elements



- 1 preheating furnace
- 2 burner
- 3 carrier with mechanical shock test mechanism
- 4 dummy
- 5 breathing machine

Fig 6 top view of the test bench

Throughout the entire test, the breathing apparatus is connected to the breathing machine which has been set at a rate of 25 cycles of breath / minute with 2 liters of air / cycle and respiratory resistance is monitored (Ilie et al, 2017). When analysing the breathing resistance graph the first three respiratory cycles after the free fall will be excluded.

## Conclusions

The use of self-contained breathing apparatus, based on compressed air, requires, prior to placing on the market, their certification.

One of the certification requirements is high temperature testing by exposing the device to a temperature of 900°C for 10 seconds.

High temperature testing involves placing the self-contained breathing apparatus in the heated oven at 90°C for 15 minutes, flame exposure with propane-air mixture for 10 s, and the shock resistance test by free fall at a height of 150 mm.

In order for the apparatus to be tested at high temperature to pass the test, it is necessary that its components do not allow flame persistence for more than 5 s after the burner is switched off and that the breathing resistance monitored by the breathing machine does not change beyond the maximum permissible value.

## References

- Ilie, C., Găman A. G., *Study on the rescuers behaviour exposed to high temperature and humidity in the INCD INSEMEX Petroșani training facility*, Occupational Health and Safety - Proceedings of the symposium ISSN 1843-6226 SESAM (2015)
- Ilie, C., Găman A. G., *Research on developing new testing methods for respiratory protection equipment*, 8th International Symposium on Occupational Health and Safety SESAM (2017)
- Ilie, C., *Developing and applying test methods for compressed air / oxygen breathing apparatus for their certification*, PN 16 43 02 23 (2017)
- SR EN 137\_2008 Respiratory protective devices. Self-contained open-circuit compressed air breathing apparatus with full face mask. Requirements, testing, marking.

# Monitoring worker's exposure to physicochemical pollutants to prevent occupational illness

Sorin Simion <sup>a,\*</sup>, Kovacs Marius<sup>a</sup>,

Toth Lorand<sup>a</sup>, Alexandru Simion<sup>a</sup>, Maria Bădescu<sup>b</sup>

<sup>a</sup>National Institute for Research and Development in Mine Safety and Protection to Explosion – INSEMEX Petroșani, 32-34 G-ral Vasile Milea Street, Postcode: 332047, Petroșani, Hunedoara County, Romania

<sup>b</sup>Colegiul Economic Hermes Petrosani, Independenței 1 Street, Postcode: 332058, Petroșani, Hunedoara County, Romania

---

## Abstract

Exposure to physicochemical pollutants in the work environment leads to occupational illnesses. Workers working in the fields of production of raw materials, energy, material goods, etc. are exposed to these noxious substances over a long period of time. Long-term exposure to many pollutants may have a cumulative effect on the worker. In order to quantify the occupational exposure generated by cumulative exposure to noxious substances, it is necessary to determine the exposure level for each harmful substance. In this respect, the current paper presents a case study, where workers carry out their activity under difficult working conditions in an environment where physicochemical pollutant concentrations exceed limits allowed by national / international legislation. Also, the paper presents the monitoring of physicochemical pollutants in order to be able to quantify the exposure of workers and their health status. Physical and chemical monitored pollutants (omnipresent in industry) are: noise, vibrations, particulate matter and chemicals used in / generated by the workplace atmosphere (CO, CO<sub>2</sub>, NO<sub>x</sub>, etc.). Disabilities resulting from the exercise of a job or profession, caused by physical and / or chemical damaging factors characteristic of work places, are difficult to diagnose in the absence of systematic monitoring of health, as causality between factors that generated occupational illness must be assessed, these being usually determined by a combination of determinants (main factors) and biasing (secondary) factors. The effects of exposure to physicochemical pollutants on health of workers are presented both quantitatively by measuring the level of exposure and from the situation of occupational illnesses point of view.

Keywords: hazardous conditions; occupational pollutant; occupational illness; exposure; risk

---

## 1. Generalization

Occupational diseases can be defined as: „those disorders that result from the exercise of a profession or occupation caused by physical, chemical or biological factors, features of the workplace and the overworking of various organs or systems of the body in the work process“. (Toma, 1985)

In order to be considered "occupational disease" or "occupational disease", the condition in question must meet certain characteristics such as:

- The onset of illness is the result of the exercise of a profession or profession;
- Physical, chemical or biological harmful factors are characteristics of the workplace;
- Overworking of different organs or systems is characteristic of the work process.

The most important feature of the causal relationship between exposure to pollution and occupational disease is the complex nature of the factors that generate them, most often the diseases are not caused by a single generator, but by a set of factors.

Within the generating factors (etiological) it is noticeable:

- a major or determinant etiological factor;
- a set of favorable or secondary etiological factors.

---

\* Corresponding author. Tel.: 004-0254-541-621; fax: 004-0254-546-277.  
E-mail address: sorin.simion@insemex.ro.

In professional pathology, the determinants (main) or the favored (secondary) factors belong to the working conditions, being generated by the existence of professional harm / noxae.

**Working conditions** consist of all the factors existing at the workplace, namely:

- physiological factors such as the intensity of physical work (predominantly muscular) or predominantly neuropsychic and sensory, duration of work, rhythm of work, monotonous work, etc.
- factors of the working environment, such as: physical factors of the working environment (temperature, humidity, speed of air currents, presence of noise and vibrations, electromagnetic radiation, etc.), chemical factors (toxic chemicals in the work environment) physicochemical factors (professional powders), biological factors (microbes, parasites, etc.)
- Ergonomic factors are determined by the human-machine relationship being a resultant between a series of elements with physiological characteristics (static effort, dynamic, working position, etc.) and features of the working environment (noise, vibrations, etc.) for example, the driver and vehicle relationship that determines a static work position with high neurophysical demand but also exposure to noise, vibration, chemical poisoning from internal combustion engines, etc.
- psychosocial factors such as teamwork, motivation of work, positive / negative appreciation, subordinate relationship, etc.

When one or more factors defining working conditions have a negative effect on health and / or work capacity, and thus become factors generating occupational illness, they are defined as occupational harm / noxae. (Toma, 1985)

## **2. Case study on occupational exposure to physicochemical pollutants**

The investigations carried out in this paper have been carried out on a steelwork the subject of activity of the company is the production of ferrous metals in primary and ferroalloy forms - CAEN code 2410.

The technological flow is of modern design based on the production of steel in furnaces.

The electric steel factory has a stream of in-line production, so it exists:

- - storage area on assortments of scrap iron;
- - berthing area of scrap iron;
- - the furnace loading area with the old iron in the bonnet;
- - the steel making area in the electric furnace;
- - the area of the steel treatment in the pot;
- - the area of the steel depot.

### **Description of the activities carried out by the factory staff:**

- loading the oven with a scrap iron;
- handling and transportation of raw materials and materials (lime, ferro-alloys, slag foaming material, furnace maintenance materials, etc.)
- melting scrap iron in the oven;
- dosing and administration of the addition materials in the oven and pot;
- injecting oxygen and slag foaming materials into the oven;
- kiln sampling, primary chemical analysis, slag analysis, temperature;
- assuring the furnace with casting pots for the purpose of download;
- assuring the oven with slag pots;
- emptying the slag pots and evacuating the slag from the hall;
- evacuating the liquid steel from the furnace to the casting pot;
- transporting the liquid steel pot to the LF plant;
- treatment of steel in the pot at the LF plant (steel alloy - through corrections necessary for final chemical analysis);
- sampling for final chemical analysis;
- slag cleaners, steel blasts, flue gas extraction systems, smoke channels, etc.
- changing the electrode columns from the furnace and LF installation;
- servicing the electric furnace (EBT) and the steel treatment plant (LF) by means of cranes;
- transporting the casting chamber filled with liquid steel in order to be taken over by the crane from the continuous casting machine;
- placing the casting pot on the rotary tower of the MTC;
- providing the necessary materials for the continuous casting process (protection tubes, casting powders, etc.);
- casting of steel into profiles (round tags);
- installing / removing the drawer to open the pot;
- cutting, hot marking, cooling and evacuation of tags;
- rewriting tags, marking by dyeing, tagging and tagging;
- maintenance of electrical, mechanical, hydro-thermal, etc., of all the machinery from the steelworks and of the continuous casting machine

In order to monitor exposure to professional pollutants, INCD INSEMEX Petroșani has made determinations for the main occupational noxious substances in the work environment.

The manufacture of steel products mainly generates exposure to the following professional noises, noise, vibration, dust, carbon monoxide and carbon dioxide.

The method of determining the method of determination of these occupational harm / noxae is the direct method of measuring devices with numerical display.

The results of the determination of the occupational harm / noxae in accordance with the regulations in force are presented in Table 1. (GD 493/2006, GD 1876/2005, GD 359/20015)

Table no. 1.

Work place	Noise Exposure limit (87dB(A) GD 493/2006	Global vibrations Exposure limit (1,15 m/s <sup>2</sup> ) GD 1876/2005	Breathable breathing particles from the suspension Exposure limit (5 mg/m <sup>3</sup> ) GD 359/2015	CO <sub>2</sub> Exposure limit (9000 mg/m <sup>3</sup> ) GD 359/2015	CO Exposure limit (30 mg/m <sup>3</sup> ) GD 359/2015
Electric Furnace (EBT)	105.5	1.82	1.15	534	3.21
Steel treatment plant (LF)	91.6	1.01	0.16	320	1.23
Pouring potting sector	90.4	1.62	7.52	620	1,65
The steel vacuuming plant	91.6	1.25	2.4	320	1.25
Continuous casting workshop	90.2	1.59	1.25	420	1.22
Flue gas capture and treatment plant	87.5	1.55	8.71	250	1.02
Crystallizing hall	90.8	1.02	6.12	620	1.23
Crane bridge cabine	84.2	1.25	25.15	836	2.47
Masonry formation	95.6	2.98	13.17	906	1.23

Exceeding the level of exposure to these noxes generated by the individual and / or cumulative effect of a series of occupational or profession related illnesses over a 5-year monitoring period are presented in table .2.

Table no. 2.

Disease related to the profession	Causal professional factors	2017	2016	2015	2014	2013
Cardiac disorders (HTA CIGD) (pers.)	Noise, vibration, temperature, high caloric radiation, increased neurophysiological stress	114	106	113	128	100
Respiratory disorders (pers.)	Dusts, irritating gases, organic solvents	31	31	31	18	6
Hearing disorders (pers.)	Noise, chemical harm / noxae	4	12	12	6	8
Osteo-muscular joint disorders (TIW days)	Unfavorable microclimate, vibration, increased effort, inconvenient posture, mechanical traumatic effect	457	401	349	264	420

In conclusion, there is a decrease in the number of occupational diseases as a result of the implementation of the plans for measures regarding the reduction of the occupational exposure to physicochemical risk factors and the awareness of the employees regarding the use of PPE and observance of the working instructions. Also, the result of medical assessments demonstrates that in these jobs activities are carried out in the presence of physicochemical noxes, which indicates a risk control, without being eliminated due to the characteristics of the activities carried out (Băbuș, 2011).

### 3. Conclusions

Following the determination of the noxiousness in the workplaces in order to assess their impact on the health status of the personnel involved in the steelworks, the following conclusions were drawn:

- Periodic measurements of professional pollutants are widely used to confirm or deny their existence in their work environment. Occupational exposure monitoring is mainly performed to verify the exposure level, respectively to comply with the limit values set by applicable legislation and to establish a plan of measures to reduce occupational harm / noxae.
- The permanent medical surveillance carried out by the labor medicine cabinets within the compulsory medical control quantifies the number of occupational illnesses and occupational harm / noxae susceptible to its occurrence.
- Quantification of occupational exposure and their characteristics helps the employer determine the best methods to reduce exposure to them.

- There is a decrease in the number of occupational illnesses as a result of the implementation of the action plans on the reduction of occupational exposure to physicochemical risk factors and employee awareness of the use of PPE and the observance of the working instructions
- Conclusively, the steelworks presented above should continue to modernize and optimize the production process by implementing new technologies that provide increased protection for workers. Due to the specific nature of the activity carried out, it is not possible for the production process to take place automatically without the direct participation of the worker. This requires the adoption of a system that integrates several variables, namely: competitiveness, economic development, health and safety at work, through differentiated approaches, short, medium and long term.

## **Acknowledgements**

This paper was developed within the Nucleu-Programme, carried out with the support of Romanian Ministry of Research and Innovation, project no. PN-18-17-02-02, project title: Research on improving health and safety in hazardous environments with explosive, flammable and toxic atmospheres (in Romanian: Cercetări privind îmbunătățirea stării de securitate și sănătate în medii periculoase cu atmosfere explozive, inflamabile și toxice)

## **References**

Băbuț, G.B., Moraru, R.I., Cioca, L.I., „*Kinney methods*”: *useful or harmful tools in risk assessment and management process?*, Proceedings of the 5th International Conference on Manufacturing Science and Educations (MSE 2011), Volume II, pp. 315-318, Sibiu, Romania, 02-05.06. (2011)

Toma, N., *Manual of Professional Pathology*, Medical Publishing House, București, (1985)

Law 319/2006 *on Safety and Health at Work*

GD 493/2006 *concerning the risks posed by noise*

GD 1876/2005 *on vibration-related risks*

GD 359/2015 *on Safety and Health at Work*

## Study on the anticorrosive phosphated steel carabiners used at personal protective equipment

Costică Bejinariu<sup>a</sup>, Diana-Petronela Burduhos-Nergis<sup>a</sup>, Nicanor Cimpoesu<sup>a</sup>, Mihai-Adrian Bernevig-Sava<sup>a</sup>, Ștefan-Lucian Toma<sup>a</sup>, Doru-Costin Darabont<sup>b</sup> and Constantin Baciua<sup>a\*</sup>

<sup>a</sup>”Gheorghe Asachi” Technical University of Iasi, 67 Dimitrie Mangeron Blv., Iasi 700050, Romania

<sup>b</sup>INCDPM ”Alexandru Darabont”, 35A Ghencea Blv, Bucharest 061692, Romania

---

### Abstract

Personal protective equipments used by firefighters, builders or climbers includes so called carabiners made of carbon steels. In use, those connecting components - carabiners - are subject to corrosion, so the corrosion protection is requiring, such as anticorrosion phosphating. This study aims to elaborate a proper phosphating technology with two types of additives, a series of metal cations, on one hand, and surface active agents, on the other hand, with multiple roles in the nucleation processes, allowing to obtain compact layers, homogen and adherent to substrate. It also highlight the presence, form and structure of the phosphate layer.

*Keywords:* Personal Protective Equipment, Carabiner, Surface Structure, SEM-EDX, Thin Layer, Zinc Phosphate

---

### 1. Introduction

Any type of equipment used by workers to keep them safe from dangers can be considered personal protective equipment (Babut et al., 2011; Bejinariu et al., 2017a; Ivascu and Cioca, 2014).

Depending of the area it protects, the personal protective equipment is classified in head protection (hard hats), foot protection (boots), hearing protection (earplugs), hand and arm protection (gloves), eye and face protection (goggles), respiratory masks and body protection (harnesses).

If workers are operating in areas where risk of falling is present and technical measures do not provide adequate protection, workers must use harnesses or safety belts, including necessary accessories, such as safety ropes, hooks, etc. (Babut and Moraru, 2018; Bejinariu et al, 2017b; Darabont et al., 2017a; Moraru et al., 2013).

Full body harness contains: a waist belt, generally made of polyamide straps that are sewn and connected by metal buckles, positioning rope, descender, rope graps and lanyard assembly (Blair et al., 2005; Bright, 2014).

There are two types of connectors used at fall arrest equipments: carabiners and hooks.

The carabiner is a small metallic shackle with an inward opening gate used as a link between climbing equipment and anchoring point.

Due to their importance for personal safety, these are used in various fields such as: caving, arboriculture, industrial rope work, sports mountaineering, canoeing, fire fighting, etc.

In order to be used in safe condition, the carabiner must be compact, easy to handle and possess good chemical resistance and mechanical properties (Darabont et al., 2017b; Mihai-Adrian et al., 2017).

In this paper we aim to improve the anti-corrosion properties of the material used at carabiner's body, the components of a carabiner are shown in Fig. 1.

---

\* Constantin Baciua. Tel.: +4-072-996-9619

E-mail address: constantin\_baciua@yahoo.com

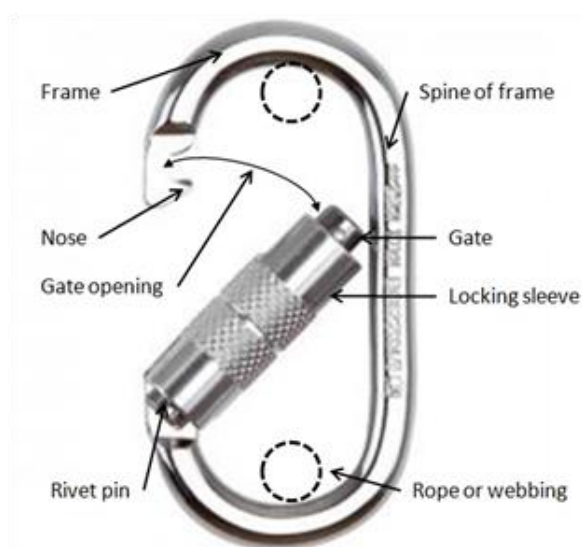


Fig. 1. Carabinier components

The most commonly used materials for carabiners manufacturing are aluminum alloys and different types of steels (Blackford, 2003).

Aluminum carabiners are used especially by rock climbers because, in this situation, the carabiner weight is the most important factor. Instead, steel carabiners are used usually by firefighters, where the refractory properties and mechanical strength comes first (Evans and Truebe, 2015; Scott, 2008).

The characteristics that a carabiner must possess are specified in the following standards: EN 362 Personal protective equipment against falls from a height. Connectors, EN 12275, Mountaineering equipment - Connectors - Safety requirements and test methods, UIAA 121, Mountaineering and Climbing Equipment - Connectors, Union (EN 362, 2004; EN 12275, 1998; UIAA 121, 2004).

EN 362: 2004 is the only standard that includes specifications about corrosion resistance properties of the carabiner, according to this the presence of corrosion on base material is not accepted, but the presence of some oxides stains is acceptable (EN 362, 2004).

In order to improve corrosion resistance, this study aims to elaborate a proper phosphating technology with two types of additives, a series of metal cations, on one hand, and surface active agents, on the other hand, with multiple roles in the nucleation processes, allowing to obtain compact layers, homogen and adherent to substrate. (Lazar et al., 2017; Sandu et al., 2010) The presence, form and structure of the phosphate layer is also highlighted.

## 2. Phosphating process

Among metal surface corrosion protection general techniques, phosphating has an important place (Buzea et al., 2009; Nica et al., 2012; Sandu et al., 2012). The phosphating process consists in forming of a protective film of insoluble phosphates on the metal surface. This process is cheap and simple because it doesn't involve expensive raw materials, complex machinery and highly qualified personnel (Bejinariu et al., 2010; Earar et al., 2015).

Depending on the environment and process conditions, the phosphate coatings are of two kinds, namely crystalline and amorphous. The crystalline coating present greater interes for industrial application, this having ferrous substrates such as carbon steel, low alloy steel and cast iron (Burduhos Nergis et al., 2018; Nedeff, et al., 2013; Sandu et al., 2013).

For carabiners manufacturing, specialized plants like Concezione Articoli Montagna Premana (CAMP) frequently use the 1045 steel, according to the SAE J1397-1992 standard, with the chemical composition shown in Table 1 (SAE J1397, 1992).

This study was made on steel samples equivalent to 1045 steel, namely C45 steel, which chemical composition according to the standard SR EN 10083-2 is presented in Table 2 (SR EN 10083-2, 2006), and samples chemical composition obtained by EDAX means is shown in Table 3.



Table 1. Chemical composition of 1045 (SAE J1397, 1992)

Element chimic	Minim	Maxim
C	0.43	0.50
Mn	0.60	0.90
P		0.040
S		0.050
Si	0.10	0.25
Cu	0.20	
B	0.0005	0.0030
Pb	0.10	0.35

Table 2. Chemical composition of C45 according to standard (SR EN 10083-2, 2006)

Element chimic	Minim	Maxim
C	0.42	0.50
Mn	0.50	0.80
P		0.04
S		0.045
Si	0.17	0.37
Ni		0.30
Cr		0.30
Cu		0.30
As		0.05

Table 3. Chemical composition of C45 samples

Element	Fe	C	Si	Mn	P	Cu	Cr
Percent	balance	0.45	0.22	0.78	0.02	0.15	0.17

The phosphating process of C45 samples consist in multiple main and secondary stages, which are presented in Fig. 2.

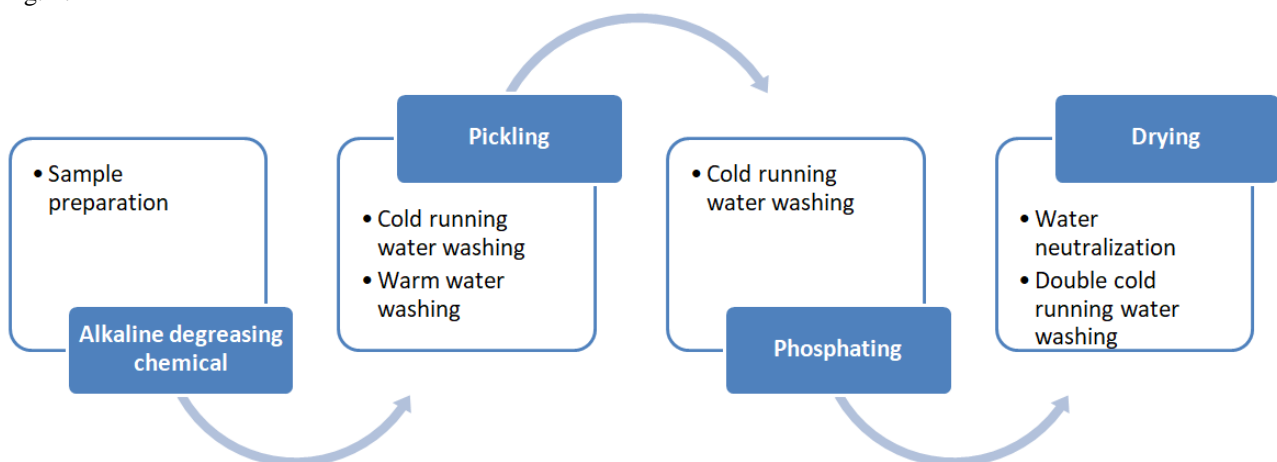


Fig. 2. Phosphating process staages of C45 samples

After crystalline phosphating, a layer of zinc phosphate tetrahydrate  $\text{Zn}_3(\text{PO}_4)_2 \cdot 4\text{H}_2\text{O}$  is formed on the C45 steel samples surface, metallic bonded to the base material. The general surface of the simple and phosphated C45 steel samples is shown in Fig. 3.



Fig. 3. General surface of studied sample (a) Initial sample; (b) Phosphated sample

For the alkaline degreasing bath, the following components were used: sodium hydroxide (NaOH), sodium carbonate ( $\text{Na}_2\text{CO}_3$ ), trisodium phosphate ( $\text{Na}_3\text{PO}_4 \cdot 10\text{H}_2\text{O}$ ), sodium silicate ( $\text{Na}_2\text{SiO}_3 \cdot 9\text{H}_2\text{O}$ ) and surfactant detergent. In the first main stage the samples were kept for 10 minutes in the degreasing solution heated to 85 °C.

The solution used for pickling of C45 steel samples consists of: hydrochloric acid (HCl), hexamethylenetetramine ( $\text{C}_6\text{H}_{12}\text{N}_4$ ) and sodium sulphate ( $\text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O}$ ). The pickling time was 20 minutes at ambient temperature.

Crystalline chemical phosphating of C45 steel samples solution, was obtained from the following components: phosphoric acid ( $\text{H}_3\text{PO}_4$ ), nitric acid ( $\text{HNO}_3$ ), zinc (Zn), sodium hydroxide (NaOH), sodium nitrite ( $\text{NaNO}_2$ ) and sodium tripolyphosphate ( $\text{Na}_2\text{P}_3\text{O}_{10}$ ). Samples were immersed for 30 minutes in the solution at 90 °C temperature.

The phosphating installation used in this study is shown in Fig. 4.

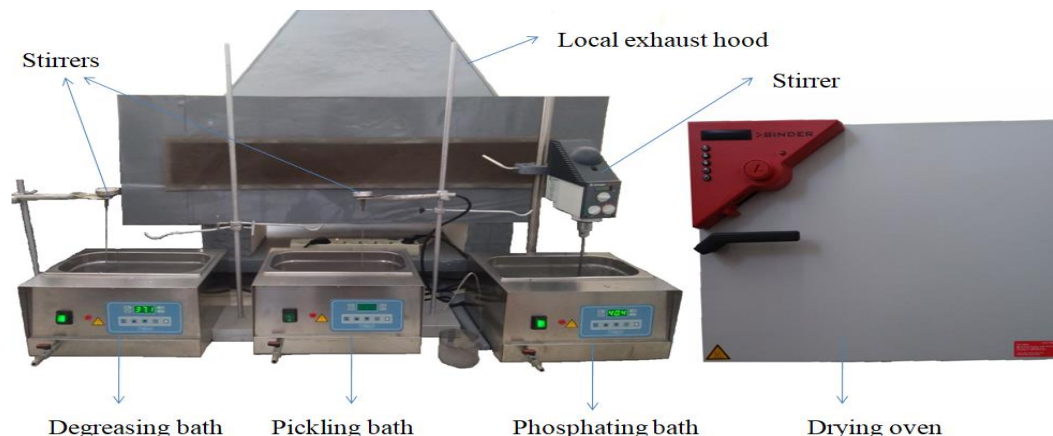


Fig. 4. General view of phosphating installation

Warming up of degreasing and phosphating solutions was done in DIGIBATH-2 Raypa digital thermostats. The agitation of the degreasing and pickling baths is carried out by means of two SIEMES 1AF 2210 0A stirrers with 220V electric motors, and the phosphating solution agitation was carried out using a R2120 Heidolph stirrer at a speed of 500 rpm. Samples drying after crystalline chemical phosphating was carried out using a APT.line™ ED (E2) model oven set at a temperature of 150 °C.

The zinc phosphate layer obtained on the C45 steel samples surface is shown in Fig. 5.

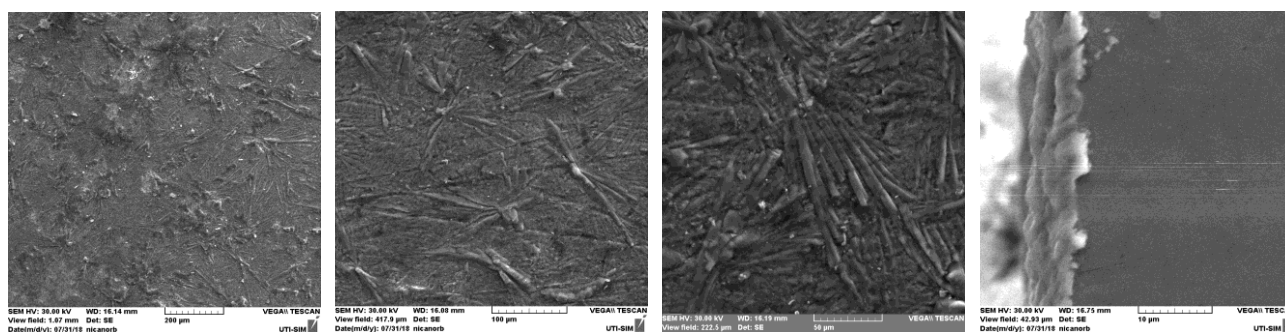


Fig. 5. Microstructure of the Zn phosphate layer obtained by means of scanning electron microscope, a) SEM microstructure, 200 µm; b) SEM microstructure, 100 µm; c) SEM microstructure, 50 µm; d) SEM microstructure, 10 µm.

### 3. Conclusions

Phosphating has been established as an intelligent solution to improve the corrosion resistance of carbon steel carabiners used in corrosive environments such as caving, navigation, construction and rescue operations.

The fine, uniform and homogeneous crystalline structure of the phosphate layer has also been achieved thanks to the high degree of surface cleaning by preliminary degreasing and pickling which also has the role of surface activation for zinc phosphate film formation by conversion.

The microstructure of the phosphate layer presents high and low areas, with intergrowth dendrites, the crystallinity of the phosphate layer being provided by sodium nitrite ( $\text{NaNO}_2$ ) from the phosphating solution.

## References

- Babut, G. B., Moraru, R. I., Occupational risk assessment: imperatives for process improvement. *Quality - Access to Success*, Vol. 19, Issue 166, pp. 133 – 144, (2018).
- Babut, G. B., Moraru, R. I., Lucian-Ionel, C. “Kinney Methods”: Useful or Harmful Tools in Risk Assessment and Management Process?, *Proceedings of the 5th International Conference on Manufacturing Science and Education*, Vol II, Sibiu, Romania, pp. 315, (2011).
- Bejinariu, C., Darabont, D.-C., Baci, E.-R., Georgescu, I.-S., Bernevig-Sava, M.-A., Baci, C., Considerations on Applying the Method for Assessing the Level of Safety at Work. *Sustainability*, Vol. 9, pp. 1263, (2017).
- Bejinariu, C., Darabont, D. C., Baci, E. R., Ionita, I., Sava, M. A. B., Baci, C. Considerations on the Method for Self Assessment of Safety at Work, *Environ. Eng. Manag. J.* Vol. 16, pp. 1395 –1400, (2017).
- Bejinariu, C., Sandu, A. V., Baci, C., Sandu, I., Toma, S.-L., Sandu, I. G. Water Treatment and Detoxification of the By-products Resulted from Lubricating Phosphatation of Iron-Based Metal Parts, *Rev. Chim.*, Vol. 61, pp. 961–964, (2010).
- Blackford, J. R., Materials in mountaineering, *Jenkins M (ed) Materials in sports equipment*, Woodhead, pp. 279-325, (2003).
- Blair, K. B., Custer, D. R., Graham, J. M., and Okal, M. H., Analysis of fatigue failure in D-shaped karabiners, *Sports Eng.*, Vol. 8, pp. 107–113, (2005).
- Bright, C. M., A History of Rock Climbing Gear Technology and Standards, *Mechanical Engineering Undergraduate Honor Theses*, (2014).
- British Standards Institution, EN 12275, Mountaineering equipment – Connectors – Safety requirements and test, *BSI Standards Limited*, (1998).
- British Standards Institution, EN 362, Personal protective equipment against falls from a height — Connectors, *BSI Standards Limited*, (2004).
- British Standards Institution, EN 10083-2, Steels for quenching and tempering. Technical delivery conditions for non alloy steels, *BSI Standards Limited*, (2006).
- Burduhos Nergis, D.P., Nejneru, C., Achitei, D.C., Cimpoiesu, N., Bejinariu, C. Structural Analysis of Carabiners Materials Used at Personal Protective Equipments, *IOP Conference Series: Materials Science and Engineering*, Vol. 374 (1), art. no. 012040, DOI: 10.1088/1757-899X/374/1/012040, (2018).
- Buzea, C. G., Bejinariu, C., Boris, C., Vizureanu, P., Agop, M. Motion of free particles in fractal space-time. *Int. J. Nonlinear Sci. Numer. Simul.*, 10, pp. 1399–1414, (2009).
- Darabont, D. C., Antonov, A. E., Bejinariu, C. Key elements on implementing an occupational health and safety management system using ISO 45001 standard, *8<sup>th</sup> International Conference on Manufacturing Science and Education - Trends in New Industrial Revolution*, Vol. 121, pp. UNSP 11007, Sibiu, România, (2017).
- Darabont, D.-C., Moraru, R. I., Antonov, A. E., Bejinariu, C. Managing new and emerging risks in the context of ISO 45001 standard, *Qual.-Access Success*, Vol. 18, pp. 11–14, (2017).
- Earar, K., Cerghizan, D., Sandu, A. V., Matei, M. N., Leata, R., Sandu, I. G., Bejinariu, C., Coman, M. The Role of Functional Polymers in the Optimization of the Acrylic Biomaterials Used in Removable Prosthetic Restoration II. Assessment of traction test and antifungal activity. *Mater. Plast.*, 52, pp. 487–493, (2015).
- Evans, T., Truebe, S., A Review of Webbing Anchor Research, *International Technical Rescue. Symposium*, Portland, Oregon, (2015).
- Ivascu, L., Cioca, L.-I. Opportunity Risk: Integrated Approach to Risk Management for Creating Enterprise Opportunities, *2<sup>nd</sup> International Conference on Psychology, Management and Social Science*, Vol. 49, pp. 77–80, Newark, USA, (2014).
- Lazar, P., Bejinariu, C., Sandu, A. V., Cazac, A. M., Corbu, O., Sandu, I. G., Perju, M. C. Corrosion Evaluation of Some Phosphated Thin Layers on Reinforcing Steel, *International Conference on Innovative Research - Icir Euroinvent*, Vol. 209, pp. 12025, (2017).
- Mihai-Adrian, B.-S., Iulian, I., Constantin, B., Costin, D. D., Alexandru, L., Marian, C. A., Costica, B. Improving safety in the workplace using checklists legal requirements. *Qual.-Access Success*, Vol. 18, pp. 31–34 (2017).
- Moraru, R. I., Babut, G. B., Cioca, L. I. Study of Methane Flow in Caved Goafs Adjacent to Longwall Faces in Valea Jiului Coal Basin, *Geoconference on Science and Technologies in Geology, Exploration and Mining, Sgem*, Vol I, pp. 731, (2013).
- Nedeff, V., Bejenariu, C., Lazar, G., Agop, M. Generalized lift force for complex fluid. *Powder Technol.*, 235, pp. 685–695, doi:10.1016/j.powtec.2012.11.027, (2013).
- Nica, P.-E., Agop, M., Gurlui, S., Bejinariu, C., Focsa, C. Characterization of Aluminum Laser Produced Plasma by Target Current Measurements. *Jpn. J. Appl. Phys.*, 51, 106102, doi:10.1143/JJAP.51.106102, (2012).
- SAE International, SAE J1397, Estimated mechanical properties and machinability of steel bars, *American National Standard*, (1992).

- Sandu, A. V., Coddet, C., Bejinariu, C. A Comparative Study on Surface Structure of Thin Zinc Phosphates Layers Obtained Using Different Deposition Procedures on Steel, *Rev. Chim.*, Vol. 63, pp. 401–406, (2010).
- Sandu, A. V., Bejinariu, C., Nemtoi, G., Sandu, I. G., Vizureanu, P., Ionita, I., Baci, C. New Anticorrosion Layers Obtained by Chemical Phosphatation, *Rev. Chim.*, Vol. 64, pp. 825–827, (2013).
- Sandu, A. V., Coddet, C., Bejinariu, C. Study on the chemical deposition on steel of zinc phosphate with other metallic cations and hexamethilen tetramine. I. Preparation and structural and chemical characterization. *J. Optoelectron. Adv. Mater.*, Vol 14, pp. 699–703, (2012).
- Scott, V., Design of a Composite Carabiner for Rock Climbing, Final Year Project, Mechanical Engineering, Imperial College London, (2008).
- UIAA, UIAA 121 Mountaineering and Climbing Equipment - Connectors, Union Internationale des Associations d'Alpinisme, (2004).

## Analysis of Chemically Deposited Phosphate Layer on the Carabiners Steel Surface Used at Personal Protective Equipments

Diana-Petronela Burduhos-Nergiș<sup>a</sup>, Carmen Nejneru<sup>a</sup>, Ramona Cimpoesu<sup>a</sup>, Alin-Marian Cazac<sup>a</sup>, Constantin Baciua<sup>a</sup>, Doru-Costin Darabont<sup>b</sup> and Costica Bejinariu<sup>a\*</sup>

<sup>a</sup>“Gheorghe Asachi” Technical University of Iasi, 67 Dimitrie Mangeron Blv., Iasi 700050, Romania

<sup>b</sup>INCDPM “Alexandru Darabont”, 35A Ghencea Blv, Bucharest 061692, Romania

---

### Abstract

It is well known the fact thus specialized type of shackles - carabiners – used at personal protective equipment work in harsh environment conditions such as high thermal variation environments for firefighters and mountain climbers, high corrosion environments for builders and seafarers. Therefore, a high corrosion resistant material must be used or a material corrosion protected, in present study, by phosphating. The aim of this study is to highlight the chemically deposited phosphate layer on connecting components surface – carabiners – made of carbon steel, by analyzing corrosion resistance of phosphate layer has also been analyzed.

Keywords: Personal Protective Equipments, Carabiner, Corrosion Test, SEM-EDX, Zinc Phosphate

---

### 1. Introduction

Fall protection equipment is required when workers perform their workload at heights and when the risk of falling is present (Babut et al., 2011). The lack of proper equipment, use of inappropriate or outworn equipment or the gear misuse can lead to high working accidents (Bejinariu et al., 2017a; Darabont et al., 2017a; Moraru et al., 2013). "Personal protection against falls from heights" means all the elements and components mounted in a certain order, with the purpose to prevent falls from heights (Darabont et al., 2017b; Earar et al., 2015).

The heights fall protection systems components are: anchor devices (this equipment is designed to provide an anchorage point from which a safety rope or a retractable stop can be mounted), positioning belts (these components are part of safety belts used for worker positioning during job activities and should support the person while using both hands), complex belts (keep under control the person movement by positioning and suspending the worker during activities), fall arrest block (it is a device that can be mounted on flexible anchor supports or rigid elements located above the work area) and connectors like hooks or carabiners (Babut and Moraru, 2018; Bejinariu et al., 2017b; Mihai-Adrian et al., 2017).

The carabiners are small metallic links with an inward opening spring gate used as a connector between climbing gear (harness) and anchor points during climbing. From the locking mechanism point of view the carabiners can be divided in: non-locking gate (with solid gate or wire gate) and locking gate (magnetic gate, twist-lock, double gate, screw gate, etc.) (Blair et al., 2005; Buzea et al., 2009; Evans and Truebe, 2015).

Due to their wide and various using areas, such as firefighting, canoeing, caving or construction, carabiners come into contact with different corrosive environments (salt water, lye used by firefighters). In these areas, the main material used in making carabiners is steel, as it has good mechanical and refractory properties. The most used steels for carabiners are and stainless steels. The main advanced of stainless steel are corrosion properties, but carbon steels possess better wear resistance (Blackford, 2003; Bright, 2014; Nedeff et al., 2013).

According to SR EN 12275 standard, a carabiner includes the following components: frame, nose, gate, locking sleeve and pins, as can be seen in Fig. 1.

---

\* Costica Bejinariu. Tel.: +4-074-575-0286  
E-mail address: costica.bejinariu@yahoo.com

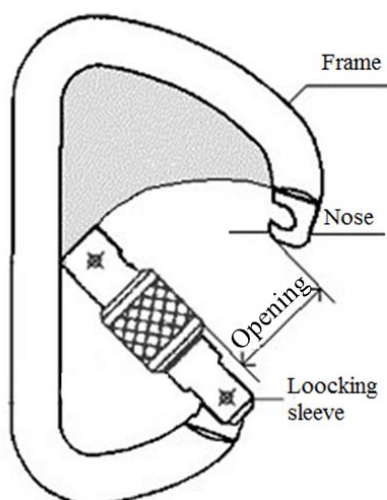


Fig. 1. Schematic presentation of a carabiner components (SR EN 12275, 1998)

The aim of this paper is to highlight the chemically deposited phosphate layer on connecting components surface - carabiners - made of carbon steel, this analysis being made by determining the corrosion resistance of phosphate layer.

## 2. Phosphated layer analysis

Phosphating is a chemical process which consists in the reaction between a metallic part surface and an acidic solution. By immersing the parts in acidic solutions, a solid phosphate surface bonded to metal is formed by chemical reaction with the base material. This layer is finely crystalline and difficult to dissolve (Bejinariu et al., 2010; Sandu et al., 2010, Sandu et al., 2012).

The phosphating process comes as a solution to improve the corrosion resistance of steel carabiners. The samples analyzed in this paper are made of C45 steel, a similar material from the chemical composition and properties point of view with the most used steels used in carabiners manufacturing (SR EN 10083-2, 2006). Fig. 2 shows the initial samples and the phosphated samples.



Fig. 2. (a) initial samples; (b) phosphated samples

### Corrosion resistance analysis

Corrosion is the physico-chemical, spontaneous and irreversible destruction of metals or alloys under the chemical, electrochemical or biological action of the environment. Corrosion processes depend on type of metal and corrosive environment, pressure and temperature conditions and static or dynamic conditions of the corrosive environment (Lazar et al., 2017; Sandu et al., 2013; Scott, 2008).

Depending to the environments, there are several factors that can influence the corrosion resistance of the carabiners material. The firefighters use steel carabiners especially due to their refractory properties. In this case, the most important corrosive factor is the used extinguishing solution (Burduhos Nergis et al., 2018; Nica et al., 2012).

In this work we studied the instant corrosion of C45 steel and C45 phosphated steel samples in a fire-extinguishing solution. A VoltaLab 40 potentiostat (PGZ301) and a three-electrode cell were used to perform the test.

The corrosion potential of corrosion current zero,  $E$  ( $I = 0$ ), Tafel slopes ( $b_a$  and  $b_c$ ), polarization resistance ( $R_p$ ), corrosion current density ( $J_{cor}$ ) as well as overlap of Tafel curves were evaluated by means of VoltaMaster 4 software.

An example of assessing the instantaneous corrosion parameters for uncoupled alloys is illustrated in Fig. 3. Since the alloy elements which dissolves are the iron and aluminum, the data used to calculate (equation 1) the corrosion rate were: for iron ( $A = 55.85$  g/mol,  $z = 2$  and  $p = 7.8$  g/cm<sup>3</sup>) and for aluminum ( $A = 26.98$  g/mol,  $z = 3$  and  $p = 2.7$  g/cm<sup>3</sup>).

In Fig. 3, the analyzed area was  $\pm 80$  mV from  $E_{\text{cor}}$  and the linear segment was 25 mV on each side of the polarization curve (cathodic Tafel region and anodic Tafel region).

$$v_p = 3,27 \cdot \left( \frac{A}{z} \right) \cdot \frac{j_{\text{cor}}}{\rho} \quad (1)$$

where:  $v_p$  is penetration rate;

$A/z$  – the electrochemical equivalent of the corroded metal in (g/val);

$\rho$  – metal density (g/cm<sup>3</sup>).

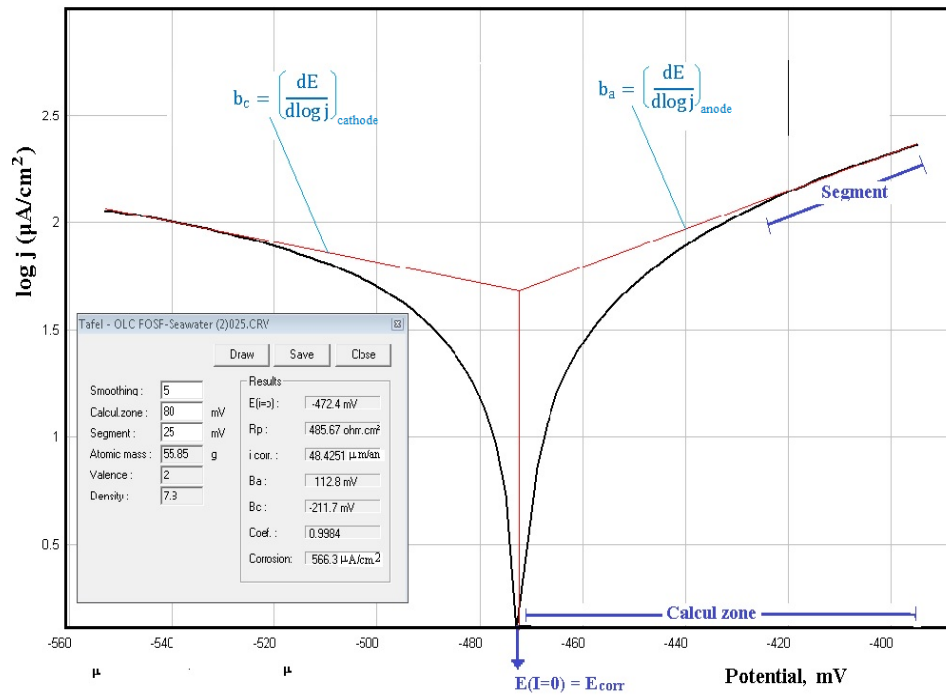


Fig. 3. Evans diagram and explanation

In this study the analyzed area was  $\pm 120$  mV from  $E_{\text{cor}}$  and the linear segment was 20 mV.

Linear polarization curves in fire-extinguishing solution and sea water for two types of steels and aluminum samples were recorded and processed in Evans diagram in order to evaluate the parameters of the instantaneous corrosion process: the corrosion potential ( $E_{\text{cor}} = E(I=0)$ ), polarization resistance ( $R_p$ ), corrosion current density ( $j_{\text{cor}}$ ), Tafel slopes ( $b_a$  and  $b_c$ ) and corrosion rate ( $v_{\text{cor}}$ ). The results are shown in Table 1 and Table 2.

Table 1. Instantaneous corrosion process parameters of analyzed samples in fire-extinguishing solution

Corrosion environment	Fire-extinguishing solution		
Alloy	C45	Phosphated C45	Duralumin
E(I=0), mV	-622	-472	-576
R <sub>p</sub> , Ohm.cm <sup>2</sup>	172,7	485,7	199,9
j <sub>cor</sub> , mA/cm <sup>2</sup>	0,144	0,079	0,136
v <sub>cor</sub> , mm/year	1,684	0,924	1,595
b <sub>a</sub> , mV/decade	53	161	44
b <sub>c</sub> , mV/decade	1147	-440	-10360



Table 2. Instantaneous corrosion process parameters of analyzed samples in Black Sea water

Corrosion environment	Black Sea water		
Alloy	C45	Phosphated C45	Duralumin
E(I=0), mV	-622	-472	-584
R <sub>p</sub> , Ohm.cm <sup>2</sup>	172,7	485,7	222,1
j <sub>cor</sub> , mA/cm <sup>2</sup>	0,144	0,079	0,125
v <sub>cor</sub> , mm/year	1,684	0,924	1,462
b <sub>a</sub> , mV/decade	53	161	67
b <sub>c</sub> , mV/decade	1147	-440	1754

As shown in Equations 2 and 3, the corrosion current density and corrosion rate are inversely proportional to the polarization resistance.

$$J_{cor} = \frac{b_a \cdot b_c}{2.303(b_a + b_c) \cdot R_p'} \quad (2)$$

$$v_{cor} = \frac{A}{zF \cdot \rho} j_{cor} \quad (3)$$

where: A/z is the electrochemical equivalent of the corroded metal in (g/val);

ρ – metal density (g/cm<sup>3</sup>);

F = 96487 C/val.

Under these parameters, the corrosion resistance differences can be analyzed based on corrosion rate values. As can be seen, the phosphated C45 steel sample present higher corrosion resistance in both corrosive environments.

According to table 2 Black Sea water is much more aggressive to C45 nonphosphate and duralumin samples than to C45 phosphate samples, but the corrosion rate differences are not significant. Also, the cathodic Tafel region slopes are larger than those for the anodic Tafel region for all samples, probably due to the complexity of the cathodic process or to speed limitations caused by diffusion processes. However, in case of duralumin sample in corrosive environments, fire-extinguishing solution and seawater (especially), the anode slopes are much larger (in absolute value) than the cathode slopes, so the polarization curves present a non-Tafelian behavior in the Evans diagram, as can be seen in Fig. 4.

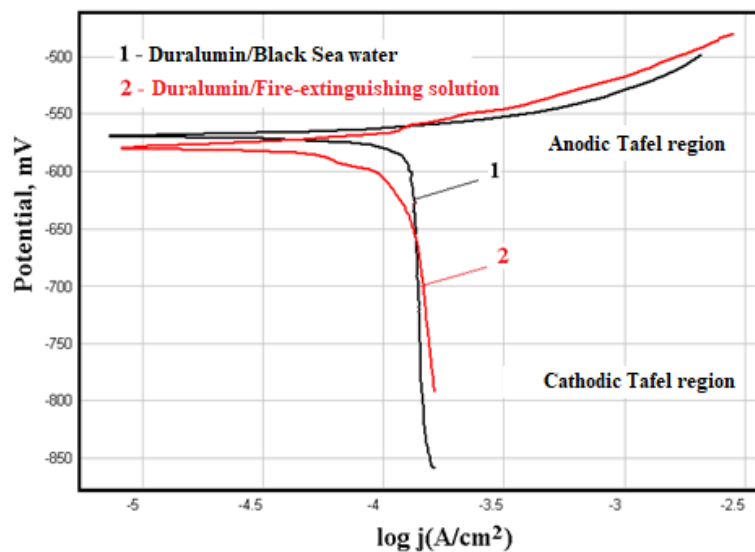


Fig. 4. The polarization curves for duralumin shows non-Tafelian behavior

This behavior is probably due to the existence of an aluminum oxides thin layer formed on the alloy surface, even in air, which restrain the diffusion reaction. In this case, in order to obtain the right corrosion parameters, both the calculation area and the linearity segment have been modified. In the case of C45 unphosphated samples the cathodic slope is much higher than the anode slope when tested fire-extinguishing solution. Another cause of these differences



can be explained by the simultaneous reduction of anode hydrogen and oxygen ions, processes favored by the lye alkalinity.

### 3. Conclusions

The environment characteristics and any solutions that come into contact with the carabiner can affect its corrosion resistance. Fire-extinguishing solutions used by firefighters can affect the mechanical properties of carbon steel carabiner. Treating the carbon steel surface by phosphating processes significantly improves the corrosion resistance of thus parts.

The phosphated film, zinc phosphate obtained, has anticorrosive protection as main application but can also be used as an anti-seize solution for friction surfaces and as a substrate for dyeing.

### References

- Babut, G. B., Moraru, R. I., Occupational risk assessment: imperatives for process improvement. *Quality - Access to Success*, Vol. 19, Issue 166, pp. 133 - 144. (2018).
- Babut, G. B., Moraru, R. I., Lucian-Ionel, C. "Kinney Methods": Useful or Harmful Tools in Risk Assessment and Management Process?, *Proceedings of the 5th International Conference on Manufacturing Science and Education*, Vol II, Sibiu, Romania, pp. 315, (2011).
- Bejinariu, C., Darabont, D. C., Baci, E. R., Georgescu, I.-S., Bernevig-Sava, M. A., Baci, C., Considerations on Applying the Method for Assessing the Level of Safety at Work. *Sustainability*, Vol. 9, pp. 1263, (2017).
- Bejinariu, C., Darabont, D. C., Baci, E. R., Ionita, I., Sava, M. A. B., Baci, C. Considerations on the Method for Self Assessment of Safety at Work, *Environ. Eng. Manag. J.* Vol. 16, pp. 1395 –1400, (2017).
- Bejinariu, C., Sandu, A. V., Baci, C., Sandu, I., Toma, S.-L., Sandu, I. G. Water Treatment and Detoxification of the By-products Resulted from Lubricating Phosphatation of Iron-Based Metal Parts, *Rev. Chim.*, Vol. 61, pp. 961–964, (2010).
- Blackford, J. R., Materials in mountaineering, *Jenkins M (ed) Materials in sports equipment*, Woodhead, pp. 279-325, (2003).
- Blair, K. B., Custer, D. R., Graham, J. M., and Okal, M. H., Analysis of fatigue failure in D-shaped karabiners, *Sports Eng.*, Vol. 8, pp. 107–113, (2005).
- Bright, C. M., A History of Rock Climbing Gear Technology and Standards, *Mechanical Engineering Undergraduate Honor Theses*, (2014).
- British Standards Institution, EN 12275, Mountaineering equipment – Connectors – Safety requirements and test, *BSI Standards Limited*, (1998).
- British Standards Institution, EN 362, Personal protective equipment against falls from a height — Connectors, *BSI Standards Limited*, (2004).
- British Standards Institution, EN 10083-2, Steels for quenching and tempering. Technical delivery conditions for non alloy steels, *BSI Standards Limited*, (2006).
- Burduhos Nergiş, D.P., Nejneru, C., Achitei, D.C., Cimpoeşu, N., Bejinariu, C. Structural Analysis of Carabiners Materials Used at Personal Protective Equipments, *IOP Conference Series: Materials Science and Engineering*, Vol. 374 (1), art. no. 012040, DOI: 10.1088/1757-899X/374/1/012040, (2018).
- Buzea, C. G., Bejinariu, C., Boris, C., Vizureanu, P., Agop, M. Motion of free particles in fractal space-time. *Int. J. Nonlinear Sci. Numer. Simul.*, 10, pp. 1399–1414, (2009).
- Darabont, D. C., Antonov, A. E., Bejinariu, C. Key elements on implementing an occupational health and safety management system using ISO 45001 standard, *8<sup>th</sup> International Conference on Manufacturing Science and Education - Trends in New Industrial Revolution*, Vol. 121, pp. UNSP 11007, Sibiu, România, (2017).
- Darabont, D.-C., Moraru, R. I., Antonov, A. E., Bejinariu, C. Managing new and emerging risks in the context of ISO 45001 standard, *Qual.-Access Success*, Vol. 18, pp. 11–14, (2017).
- Earar, K., Cerghizan, D., Sandu, A. V., Matei, M. N., Leata, R., Sandu, I. G., Bejinariu, C., Coman, M. The Role of Functional Polymers in the Optimization of the Acrylic Biomaterials Used in Removable Prosthetic Restoration II. Assessment of traction test and antifungal activity. *Mater. Plast.*, 52, pp. 487–493, (2015).
- Evans, T., Truebe, S., A Review of Webbing Anchor Research, *International Technical Rescue. Symposium*, Portland, Oregon, (2015).
- Lazar, P., Bejinariu, C., Sandu, A. V., Cazac, A. M., Corbu, O., Sandu, I. G., Perju, M. C. Corrosion Evaluation of Some Phosphated Thin Layers on Reinforcing Steel, *International Conference on Innovative Research - Icir Euroinvent*, Vol. 209, pp. 12025, (2017).

- Mihai-Adrian, B.-S., Iulian, I., Constantin, B., Costin, D. D., Alexandru, L., Marian, C. A., Costica, B. Improving safety in the workplace using checklists legal requirements. *Qual.-Access Success*, Vol. 18, pp. 31–34 (2017).
- Moraru, R. I., Babut, G. B., Cioca, L. I. Study of Methane Flow in Caved Goafs Adjacent to Longwall Faces in Valea Jiului Coal Basin, *Geoconference on Science and Technologies in Geology, Exploration and Mining, Sgem*, Vol I, pp. 731, (2013).
- Nedeff, V., Bejenariu, C., Lazar, G., Agop, M. Generalized lift force for complex fluid. *Powder Technol.*, 235, pp. 685–695, doi:10.1016/j.powtec.2012.11.027, (2013).
- Nica, P.-E., Agop, M., Gurlui, S., Bejinariu, C., Focsa, C. Characterization of Aluminum Laser Produced Plasma by Target Current Measurements. *Jpn. J. Appl. Phys.*, 51, 106102, doi:10.1143/JJAP.51.106102, (2012).
- Sandu, A. V., Coddet, C., Bejinariu, C. A Comparative Study on Surface Structure of Thin Zinc Phosphates Layers Obtained Using Different Deposition Procedures on Steel, *Rev. Chim.*, Vol. 63, pp. 401–406, (2010).
- Sandu, A. V., Bejinariu, C., Nemtoi, G., Sandu, I. G., Vizureanu, P., Ionita, I., Baci, C. New Anticorrosion Layers Obtained by Chemical Phosphatation, *Rev. Chim.*, Vol. 64, pp. 825–827, (2013).
- Sandu, A. V., Coddet, C., Bejinariu, C. Study on the chemical deposition on steel of zinc phosphate with other metallic cations and hexamethilen tetramine. I. Preparation and structural and chemical characterization. *J. Optoelectron. Adv. Mater.*, Vol 14, pp. 699–703, (2012).
- Scott, V., Design of a Composite Carabiner for Rock Climbing, Final Year Project, *Mechanical Engineering*, Imperial College London, (2008).
- UIAA, UIAA 121 Mountaineering and Climbing Equipment - Connectors, *Union Internationale des Associations d'Alpinisme*, (2004).

## Increase in the security quality in use of professional pyrotechnic articles falling in category F4

Cristian Radeanu\*, Attila Kovacs, Daniela Rus, Ilie Ciprian Jitea, Gabriel Dragos Vasilescu

*National Institute for Research and Development in Mine Safety and Protection to Explosion-INSEMEX Petrosani, 32-34G-ral. Vasile Milea Street, 332047 Petrosani, Romania*

---

### Abstract

The importance of the specific risk assessment of the Category 4 pyrotechnic articles is based on the following considerations: (1) in relation to the F1, F2 and F3 category pyrotechnic articles, these products present a significantly higher level of risk due to the mode of operation and the potency of the explosive substance involved, requiring authorized personnel as a pyrotechnician; (2) the national regulations do not have explicit provisions for this type of high-risk product, and the implementation of the European Standards Harmonized with the 2013/29 / EU Directive offers the possibility of testing, evaluation or technical expertise appropriate to the level of current scientific knowledge. The tests were carried out on F4 category professional pyrotechnic products, using the updated test procedure, corroborated with the variation of the principle scheme for measuring and determining the main parameters.

*Keywords:* quality management security, pyrotechnic article for professional use, functional testing

---

### 1. Introduction

The importance of the specific risk assessment of the Category 4 pyrotechnic articles is based on the following considerations:

- in relation to the F1, F2 and F3 category pyrotechnic articles, these products present a significantly higher level of risk due to the mode of operation and the potency of the explosive substance involved, requiring authorized personnel as a pyrotechnician (Kovacs A., 2007);
- the national regulations do not have explicit provisions for this type of high-risk product, and the implementation of the European Standards Harmonized with the 2013/29/EU Directive offers the possibility of testing, evaluation or technical expertise appropriate to the level of current scientific knowledge (Covello V.T., Merkhofer M.W., 1993; Conte, Rubio, Garcia, 2011; Directiva 2013/29/UE, 2013).

Tests have been performed on category F4 pyrotechnical articles, using the updated testing procedure in conjunction with the principle schematic diagram for the measurement and determination of the impulse, of the ascension height (Leba et al., 2014), customized for the case where the angle of deviation in the  $\beta_{1,2}$  horizontally plane is different from 0 and the video cameras are located at the same level as the launch point, thus determining a safe distance which corresponds to the condition of recording a maximum noise level (impulse) of 120 dB (A) at its upper limit (Cioara C., R. et.al., 2018; Kotus J, Kostek B, 2008). Equipment used for the determinations performed within INSEMEX testing facility, which have to reproduce the real conditions of use, have a measurement accuracy and a range of action with respect to the coverage range of the parameter range required to be determined, superior to those provided for the lower categories (PN 16 43 02 20, 2016-2017).

### 2. Considerations on the methodology for carrying out tests specific to pyrotechnic articles for professional use (category F4)

Tests for pyrotechnic articles for professional use (category F4) were performed on the basis of the PI-98 procedure entitled "Verification of the operation of pyrotechnic articles", by applying the methodology developed in accordance to the provisions of standard SR EN 16261-3: 2013, (Rus D., Vasilescu G, Kovacs A., et.al., 2017; Rădeanu Cristian, et. al., 2018).

---

\* Corresponding author. +4-072-720-0773; fax: +40-254-545-277.  
E-mail address: cristian.radeanu@insemex.ro.

The main tests/testing requirements for the sections covered by the applicable standard method focused on the following technical aspects (Pasculescu et al., 2014, and Pasculescu et al., 2015): construction and stability (external dimension of the article, caliber determination, gross mass determination); design-verification; angle of ascension and height of explosion (Pasculescu et al., 2012); measurement of the sound pressure level; extinction of flames; visual and sound inspections; mechanical conditioning; thermal conditioning; operating test (see the schematic diagram of Figure 1).

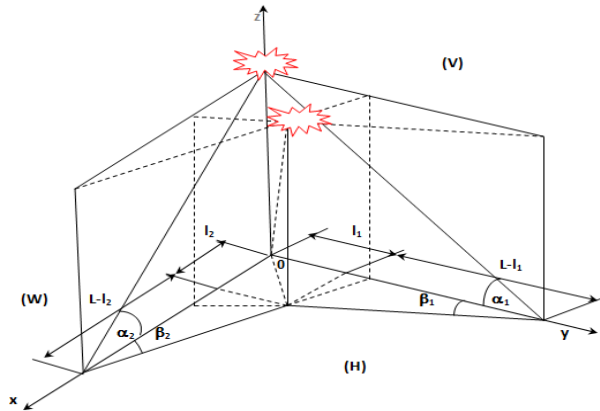


Fig.1- Principle diagram for the testing of pyrotechnic articles for professional use (category F4)

Having as hypothesis data:  $L[m]$ ,  $L_{A_{max}}[dB(A)]$ ;  $\alpha_1=\alpha_2[^\circ]$ ;  $(H)\perp(V)\perp(W)$ , where (H),(V),(W) represent the three planes (horizontally, vertically and laterally), and the following mathematical calculus relationships provided in the applicable method standard:  $h_1 = L \operatorname{tg}\alpha_1[(\cos\beta_2-\sin\beta_2)/\cos(\beta_1+\beta_2)]$ , m;  $h_2 = L \operatorname{tg}\alpha_2[(\cos\beta_1-\sin\beta_1)/\cos(\beta_1+\beta_2)]$ , m;  $H = (h_1+h_2)/2$ , m;  $r_s \geq 10^{\lg L - (L_{A_{max}} - L_{AI})/20}$ , m.

Test have been performed on pyrotechnic articles in category F4 type MINORI BCS 3 "SHELL" (figure 2) of Turkish origin, using the state-of-the-art test infrastructure within INCD-INSEMEX Petroșani testing facility, consisting of: video surveillance and results processing system consisting of 2 cameras mounted on a tripod type HDR-PJ530E which provides accurate precision for setting the ascension height, the extent of the burst effect and possible angular deviations from the optimal trajectory; DELL Inspiron 3537 laptop for information processing; stopwatch; anemometer; analytical balance; climatic room / oven; class 0 integrator sound level meter used for noise measurement, a tool which ensures precise determination of peak sound pressure values; shock apparatus; device for measuring effect, ascending, breaking and falling from a height; goniometer etc. Also, the data recording and processing system is well calibrated, being tested in an inter-laboratory testing program with similar European bodies, resulting in proper results, the deviation from the test mean being below 2%, (PN 16 43 03 20, 2016-2017).



Fig. 2- Professional pyrotechnic article (category F4) type MINORI BCS 3 "SHELL"

### 3. Results obtained from tests performed on pyrotechnic articles for professional use (category F4)

The results of the measurements performed on samples of pyrotechnic articles for professional use (samples of products tested in the original form -  $E_{FI}$ , samples of products tested after  $E_M$  mechanical conditioning and samples of products tested after thermal  $E_T$ -conditioning), which were obtained with 2 video recording cameras (Camera 1 and Camera 2) are summarized in Table 1, (Rădeanu Cristian, et. al., 2018; Jitea I.C., Vasilescu G, Kovacs A., et.al., 2016; Jitea I.C., Kovacs A., Vasilescu G, et.al., 2017).

Table 1

Pyrotechnic article code	Color	Conditioning: Initial form (E <sub>FI</sub> ) Mechanical (E <sub>M</sub> ) Termical (E <sub>T</sub> )	MEASUREMENTS		
			Filming equipment	Film camera no. 1	Film camera no. 2
BCS 3'' - 3	PURPLE	E <sub>FI</sub>	A- Breaking height (m)	61,27	60.86
			B- Height of effect (m)	87,73	89.73
			C- Effect Width (m)	58,07	54.49
			D- The height of the fall (m)	34,99	34.41
			Angle deviation from vertical ( grd.°)	1,47	1,36
BCS 3'' - 6	BLUE	E <sub>FI</sub>	A- Breaking height (m)	70.87	71.56
			B- Height of effect (m)	104.43	105.14
			C- Effect Width (m)	63.04	60.86
			D- The height of the fall (m)	38.36	41.97
			Angle deviation from vertical ( grd.°)	0.87	0
BCS 3'' - 2	GREEN	E <sub>FI</sub>	A- Breaking height (m)	-	79.67
			B- Height of effect (m)	-	108.90
			C- Effect Width (m)	-	54.24
			D- The height of the fall (m)	-	55.71
			Angle deviation from vertical ( grd.°)	-	4.98
BCS 3'' - 3	PURPLE	E <sub>M</sub>	A- Breaking height (m)	92.70	87.66
			B- Height of effect (m)	137.81	130.13
			C- Effect Width (m)	88.09	84.30
			D- The height of the fall (m)	52.92	46.46
			Angle deviation from vertical ( grd.°)	0	4.93
BCS 3'' - 1	RED	E <sub>M</sub>	A- Breaking height (m)	79.25	72.72
			B- Height of effect (m)	107.97	97.71
			C- Effect Width (m)	63.25	51.21
			D- The height of the fall (m)	46.16	42.40
			Angle deviation from vertical ( grd.°)	4.26	0
BCS 3'' - 4	YELLOW	E <sub>M</sub>	A- Breaking height (m)	60.07	62.61
			B- Height of effect (m)	87.97	93.91
			C- Effect Width (m)	50.29	48.14
			D- The height of the fall (m)	37.32	40.37
			Angle deviation from vertical ( grd.°)	3.56	3.75
BCS 3'' - 2	GREEN	E <sub>T</sub>	A- Breaking height (m)	75.70	73.96
			B- Height of effect (m)	110.85	108.78
			C- Effect Width (m)	68.26	68.62
			D- The height of the fall (m)	45.01	43.22
			Angle deviation from vertical ( grd.°)	4.77	0.8
BCS 3'' - 5	WHITE	E <sub>T</sub>	A- Breaking height (m)	71.79	71.90
			B- Height of effect (m)	97.24	98.17
			C- Effect Width (m)	51.62	52.76
			D- The height of the fall (m)	47.98	48.56
			Angle deviation from vertical ( grd.°)	1.30	3.84
BCS 3'' - 6	BLUE	E <sub>T</sub>	A- Breaking height (m)	61.09	61.87
			B- Height of effect (m)	93.24	92.81
			C- Effect Width (m)	65.18	65.03
			D- The height of the fall (m)	26.28	24.62
			Angle deviation from vertical ( grd.°)	0.16	1.36

The table below shows the results obtained from the testing of the MINORI BCS 3 "SHELL professional pyrotechnic articles in compliance with the applicability of the standardized requirements for the determined / verified parameters (see Table 2).

Table 2

POINT OF STANDARD 16261-3	PARAMETER	APLICABILITY	RESULT
6.1.	<b>Construction and stability</b>		Cylindrical shape
6.1.1.	External dimension of the article	A	H = 94 mm
6.1.2.	Determination of caliber	A	Ø 67,7 mm
6.1.3.	Determination of gross mass	A	205 g
6.2.	<b>Designing - verification</b>	A	Cardboard body, outer latex wick. The construction is in accordance with the drawing in the specification
6.4.	<b>Angle of ascension and height of explosion.</b>	A	<b>Angle of deviation from vertical (°):</b> 1,415(E <sub>SI</sub> ); 0,87(E <sub>SI</sub> ); 4,98(E <sub>SI</sub> ); 4,93(E <sub>M</sub> ); 4,26(E <sub>M</sub> ); 3,655(E <sub>M</sub> ); 2,785(E <sub>T</sub> ); 2,57(E <sub>T</sub> ); 0,76(E <sub>T</sub> ); <b>The height of the explosion (m):</b> 61,065(E <sub>SI</sub> ); 71,215(E <sub>S</sub> ); 79,67(E <sub>S</sub> ); 90,18(E <sub>M</sub> ); 75,985(E <sub>M</sub> ); 61,34(E <sub>M</sub> ); 74,83(E <sub>T</sub> ); 71,845(E <sub>T</sub> ); 61,48(E <sub>T</sub> ); 95,8(E <sub>SI</sub> ); 114,8(E <sub>SI</sub> ); 110,8(E <sub>SI</sub> ); 113,3(E <sub>M</sub> ); 110,6(E <sub>M</sub> ); 114,2(E <sub>M</sub> ); 112,2(E <sub>T</sub> ); 112,1(E <sub>T</sub> ); 113,6(E <sub>T</sub> );
6.5.	<b>Measurment of the noise pressure llevel (dB), 25m.</b>	A	1 s from cessation of functioning.
6.6.	<b>Extinguishing flames</b>	A	All products are visually and audibly responsive.
6.7.	<b>Visual and sound inspections</b>	A	
6.8.	<b>Mechanical conditioning (g)</b>	A	Weighing items before and after mechanical conditioning: 1: 208,28 – 208,25; 2: 199,2 – 199,16; 3: 206,87 – 206,83.
6.9.	<b>Termical conditioning</b>	A	Conditioned at 750 °C for 48 hours, no signs of ignition or chemical reaction.
6.10.	<b>Functional testing</b>	A	All products are functional.
6.10.3	Monitor the effect, the height of the ascent / explosion and the fall (m).	A	<b>Height of effect:</b> 88,73(E <sub>SI</sub> -Purple); 104,785(E <sub>SI</sub> -Blue); 108,9(E <sub>SI</sub> -Green); 133,97(E <sub>M</sub> -Purple); 102,84(E <sub>M</sub> -Red); 90,94(E <sub>M</sub> -Yellow); 109,815(E <sub>T</sub> -Green); 97,705(E <sub>T</sub> -White); 93,025(E <sub>T</sub> -Blue). <b>Effect Width:</b> 56,28(E <sub>SI</sub> -Purple); 61,95(E <sub>SI</sub> -Blue); 54,24(E <sub>SI</sub> -Green); 86,195(E <sub>M</sub> -Purple); 57,23(E <sub>M</sub> -Red); 49,215(E <sub>M</sub> -Yellow); 68,44(E <sub>T</sub> -Green); 52,19(E <sub>T</sub> -Whit); 65,105(E <sub>T</sub> -Blue). <b>The height of the fall:</b> 34,7(E <sub>SI</sub> -Purple); 40,165(E <sub>SI</sub> -Blue); 55,71(E <sub>SI</sub> -Green); 49,69(E <sub>M</sub> -Purple); 44,28(E <sub>M</sub> -Red); 38,845(E <sub>M</sub> -Yellow); 44,115(E <sub>T</sub> -Green); 48,27(E <sub>T</sub> -Whit); 25,45(E <sub>T</sub> -Blue).

*Note:* E<sub>SI</sub>-The initial form, E<sub>M</sub>-The mechanical conditionig, E<sub>T</sub>- The termical conditionig; The wind speed during the test was less than 5 m/s.

#### 4. Discussion on the results from the testing of pyrotechnic articles for professional use (category F4)

The results obtained from the functional test for the MINORI BCS 3 "SHELL professional pyrotechnic articles aimed to determine the following parameters by means of the measurements (Camera 1 and Camera 2): A-breaking height (m), B-effect height (m), C-effect width (m), D-drop height (m), divergence angle (vertical). Figures 3 and 4 show the screen snaps of cameras 1 and 2 that capture the image sequences used to determine the previously specified parameters, (Cioara C., R., Kovacs Attila, Rădeanu Cristian, et. al., 2018).

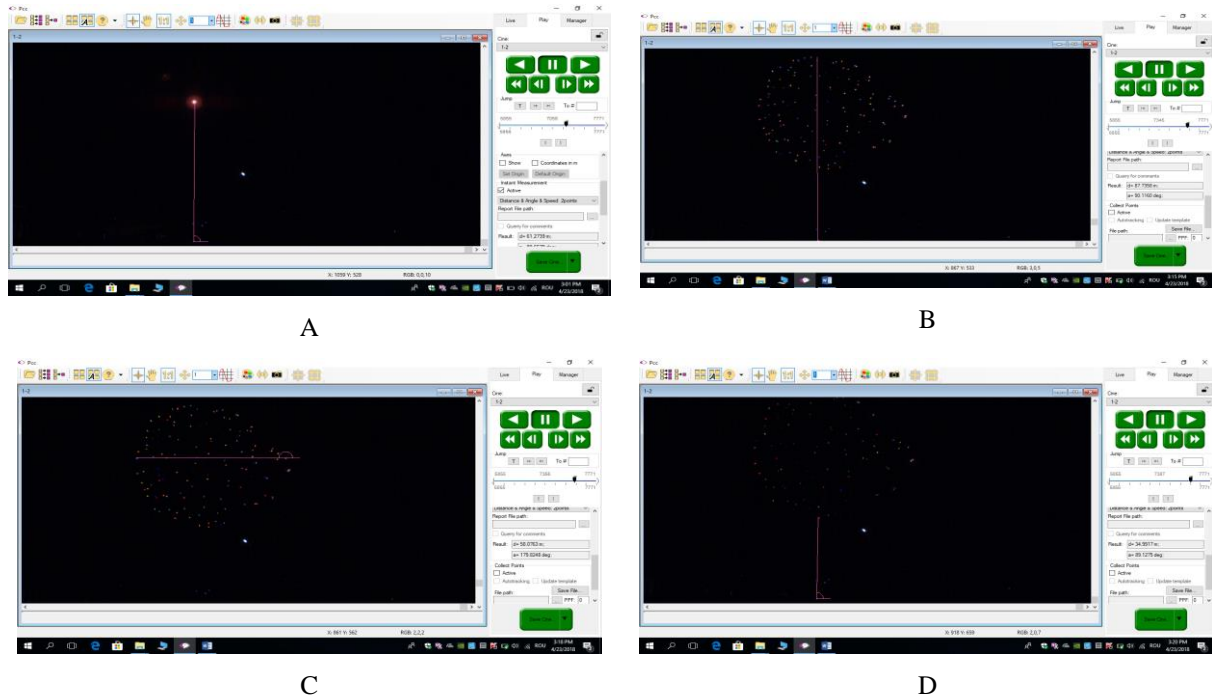


Fig.3- Camera images no.1 for the parameters of F4 category pyrotechnic articles (A-Breaking height, B-Height of effect, C-Effect Width, D-The height of the fall)

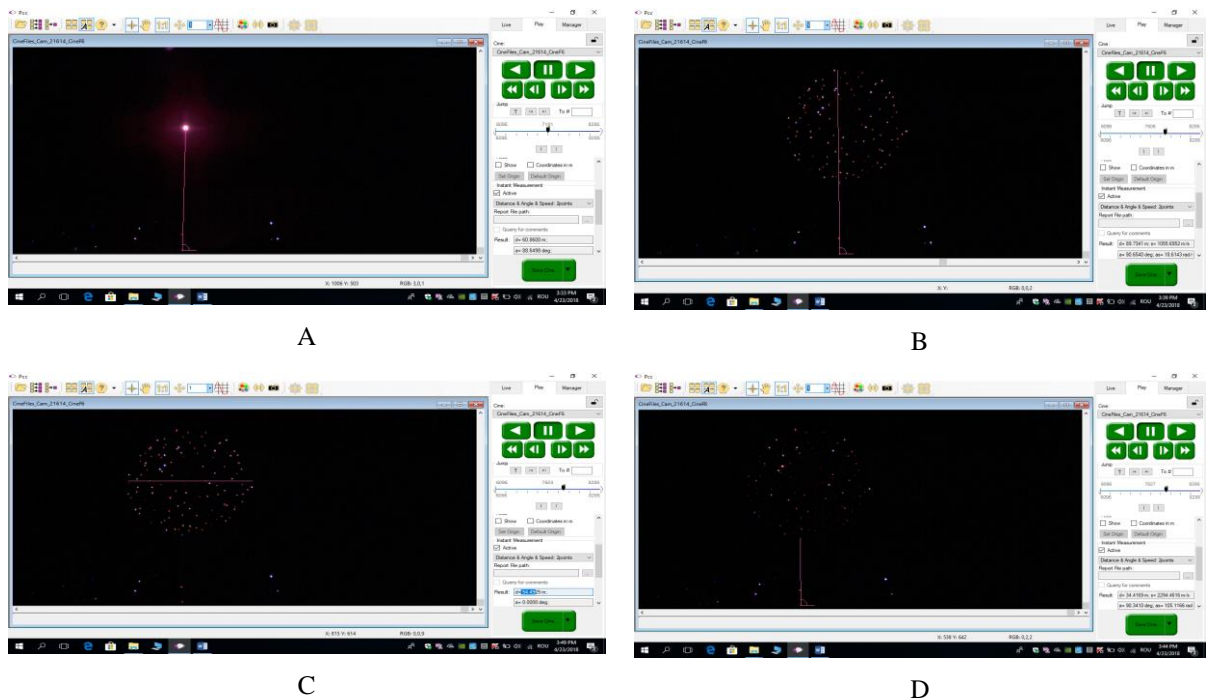


Fig.4- Camera images no.2 for the parameters of F4 category pyrotechnic articles (A-Breaking height, B-Height of effect, C-Effect Width, D-The height of the fall)

## 5. Conclusions

The implementation of the European standards family harmonized with the 2013/29/EU Directive within the framework of the testing laboratory for explosives for civil use and pyrotechnic articles LMEAP, part of the the RENAR accredited GLI-INSEMEX Group of Testing Laboratories provided the possibility of testing, evaluation / technically appropriate degree of compliance with the safety requirements for pyrotechnic articles for professional use (category F4).

Tests have been carried out on pyrotechnic articles of the MINORI BCS 3 "SHELL" category of Turkish origin, using the state-of-the-art technical test infrastructure within the INCD-INSEMEX Petroşani testing facility, in order to obtain results with high confidence concerning the parameters tested.

From the analysis of the results obtained from the tests performed on the F4 type MINORI BCS 3 "SHELL pyrotechnic articles, it is highlighted that these products comply with the requirements of the applicable standard and the technical documentation of the product, which are constructive and operational.

## References

- Cioara C.R., Şuvar Marius Cornel, Morar Marius Simion, Jitea Ciprian Ilie, Vasilescu Gabriel Dragoş „*Developement of a sustainable safety degree of the activity with pyrotechnic articles for professional use (F4)*”, Section Environmental Legislation, Multilateral Relations and Funding Opportunities, SGEM, (2018).
- Cioara C.R., Kovacs Attila, Morar Marius Simion, Jitea Ciprian Ilie, Rădeanu Cristian „*Modern training infrastructure for pyrotechnic experts according to the applicable regulations*”, EEMJ, (2018).
- Conte, Rubio, Garcia -*Occupational accidents model based on risk-injury affinity groups*, Safety science, 49, 306 – 314, (2011).
- Covello V.T., Merkhofer M.W. - *Risk Assessment Methods. Approaches for Assessing Health and Environmental Risks*, Springer, Berlin-Heidelberg-New pringer, Berlin-Heidelberg-New York, (1993).
- Directiva 2013/29/UE a Parlamentului European şi a Consiliului din 12 iunie 2013 privind armonizarea legislaţiei statelor membre referitoare la punerea la dispoziţie pe piaţă a articolelor pirotehnice, (2013).
- Hotărârea nr.1102 din 10 decembrie 2014 a guvernului privind stabilirea condiţiilor pentru punerea la dispoziţie pe piaţă a articolelor pirotehnice, (2014).
- Jitea I.C., Vasilescu G., Kovacs A., et.al. *The analysis of the influence of functioning parameters for fireworks and fireworks for professional use*, 7th International Multidisciplinary Symposium „UNIVERSITARIA SIMPRO”, Conference Proceedings, ISSN–L 1842 – 4449, Petrosani, (2016).
- Jitea I.C., Kovacs A., Vasilescu G., et.al. *Prospective analysis of ambiental and weather effects on conform displaying of fireworks*, The 8<sup>th</sup> International Conference on Manufacturing Science and Education June 7 – 9, 2017, Sibiu, România, (2017).
- Leba, M., Ionica, A., Dobra, R., Pasculescu, V.M., Quality function deployment (QFD) based expert system for renewable energy structures. A wind turbine case study, *Environmental Engineering and Management Journal*, Vol. 13, No. 6, pp. 1365-1370, (2014).
- Lee, Kim, Park-*Construction Risk Assessment Using Site Influence Factors*, Journal of computing in civil engineering, 26, 319 – 330, (2012).
- Kotus J, Kostek B, *The noise-induced harmful effect assessment based on the properties of the human hearing system*, Archives of Acoustics, 33, 4, 435-440, (2008).
- Kovacs A., *Jocurile de artificii: organizare, realizare, măsuri tehnice şi de securitate*, Editura INSEMEX, (2007).
- Marcelo Cruz,-*Operational Risk Modelling and Analysis. Theory and Practice*, published by Risk Book, a Division of Incisive Financial Publishing Ltd, London, ISBN 1-904-339-34-4, (2004).
- Pasculescu, D., Lupu, L., Pasculescu, V., Inisconi, I., Suvar, M., Study of electrocution hazards in three-phase electrical networks with ground-isolated neutral point, *Environmental Engineering and Management Journal*, Vol. 11, No. 7, pp. 1267-1271, (2012).
- Pasculescu, V.M., Pricop, D.G., Morar, M.S., Florea V.A., Research on the development of an expert system for selecting technical equipment intended to be used in potentially explosive atmospheres, *15th International Multidisciplinary Scientific Geoconference (SGEM), Informatics, Geoinformatics and Remote Sensing*, Vol. I, pp. 291-298, Albena, Bulgaria, (2015).
- Pasculescu, V.M., Radu, S.M., Ghicioi, E., Pasculescu, D., Niculescu, T., Assessing the safety level of technical equipment operating in potentially explosive atmospheres by using computer modelling, *14th International Multidisciplinary Scientific Geoconference (SGEM), Geoconference on Informatics, Geoinformatics and Remote Sensing*, Vol. I, pp. 43-50, Albena, Bulgaria, (2014).
- PN 16 43 02 20 *Cercetări privind modernizarea facilităţilor tehnice şi informatice pentru organizarea cursurilor de calificare în meseria de pirotehnician*, INSEMEX Petrosani, (2016-2017).
- Rus D., Vasilescu G., Kovacs A., et.al. *I.T. informatical platform for the certification of the explosives and pyrotechnical products* Environmental Engineering and Management, ISSN 1582-9596, June 2017, Vol.16, No.6, (2017).



## Researches on the development of spectroscopy technology used in the process of pressure networks technical verification

Cosmin Ilie<sup>1\*</sup>, Daniel Pupăzan<sup>1</sup>, Cristian Nicolescu<sup>1</sup>, Alin Irimia<sup>1</sup>, Andrei Gireadă<sup>1</sup>, Izabella Kovacs<sup>1</sup>

<sup>1</sup>National Institute for Research and Development in Mine Safety and Protection to Explosion – INSEMEX Petroșani, 32-34 G-ral Vasile Milea Street, Postcode: 332047, Petroșani, Hunedoara County, Romania

### Abstract

The decisive factor in the process of inspection of the pressure networks is determined by the correct choice of the method of carrying out the checks in order to observe with great attention the possible defects due to the physical damage resulting from the long use.

Emphasis is placed on the safety conditions of pressure equipment, which include minimum technical mandatory requirements for the periodic checking of pressurized, liquefied or dissolved gas networks.

Spectroscopy is a branch of physics that deals with the study of methods of obtaining spectra as well as measuring and interpreting them. The spectrum of electromagnetic radiation opposes its decomposition into a spectral apparatus (spectrometer) and consists of a sequence of images of the input slot formed by the different monochromatic radiation of the incident light.

Laser razors Z analyse all types of alloys: steel, stainless steel, aluminium, copper, nickel, titanium, cobalt. Wave Z spectroscopy has the best laser technology, it delivers high energy (5-6 mJ / pulse, 50 Hz) in one billionth of a second to generate gigawatt power densities - the key to a good plasma even and on the most refractory types of alloys.

The paper presents the optimal method of inspection and verification of compressed, liquefied or dissolved pressure networks, represented by the use of spectroscopy technology, in accordance with international principles and practices.

Keywords: Pressure network, spectroscopy technology, safety conditions, compressed gases, technical checks.

### 1. Introduction

Under pressure networks (fig. 1) are represented by the following categories of installations and equipment:

- Pipelines for gas, liquefied gases, pressurized gases, vapours and liquids whose vaporizing pressure at the maximum allowable temperature is at least 0.5 bar above atmospheric pressure. The pipes are tubular elements for transport of fluids when assembled in a pressurized system. These include pipes, pipe systems, piping, fittings, expansion joints and other pressure components.
- Cylinder containers, represented by any transportable recipient, in which a pressure greater than 0.5 bar can be achieved or developed in a fluid (under pressure compressed, liquefied or dissolved gases).
- Stable under pressure metal containers, installed / fitted on foundations or other stationary stands, containers installed on moving platforms or on their own mobile systems.



Fig. 1 Pressure networks

The cylinder container is an assembly consisting of:

- the under-pressure recipient having a capacity of 0.5 - 40 liters and serving for the transport and storage of compressed, liquefied or dissolved gases exposed to ambient temperature;
- the associated valves, which may be: filling and discharge devices, pressure relief devices, safety devices, measuring devices, pipe joints, fasteners fitted on container, fastenings and protective devices and protection to heat devices.

Stable under pressure metal containers are recipients having maximum permissible working pressures greater than 0.5 bar, as follows:

- containers containing 1st group gases (hazardous fluids: fluids defined as explosive, extremely flammable, highly flammable, flammable, where the maximum permissible temperature is higher than the ignition point, very toxic, toxic and oxidizing);
- containers containing 2nd group gases (steam);
- containers containing 1st group liquids;
- containers containing 2nd group liquids.

## **2. Technical control of pressure networks**

Categories of cylinder containers to be periodically checked, Technical Prescription PT C 5, 2003:

- cylinder containers for pressurized, liquefied or pressure-sensitive gases made of seamless steel, welded non-alloy steel, non-alloy aluminium and aluminium alloys with a capacity of 0.5 - 40 liters inclusive;
- set cylinders for pressurized, liquefied or dissolved gases;
- fire extinguishers;
- cylinder containers for liquefied petroleum gases (LPG), made of steel, welded, part of the liquefied petroleum gas supply systems for motor vehicles.

Cylinder containers for compressed, liquefied or dissolved pressurized gases will be subject to technical control: periodically (at the due date indicated on the container), after a repair of the container, or whenever a fault is found that could endanger safety, Technical Prescription PT C 4, 2010.

The steps to be taken in the technical control of under pressure networks are as follows: checking the general condition of the cylinders, external control, internal control, mass and capacity control, hydraulic pressure testing, leakage testing and pressure gauge testing using the ultrasonic defectoscope, Technical Prescription PT C 6, 2010.

## **3. Hydraulic pressure test**

Under pressure networks that passed outside, internal, mass and capacity control shall be subjected to hydraulic pressure test, Technical Prescription PT C 10, 2010.

Hydraulic pressure ( $P_v$ ) testing of under pressure networks is carried out at pressures higher than the loading pressure ( $P_i$ ), as follows (1):

$$P_v = 1.5 \times P_i \text{ (bar)} \quad (1)$$

The pressure test (fig. 2) will be carried out for each piece of equipment in specially designed spaces to provide protection for the other workplaces. Liquids used for the test shall not have a harmful effect on staff health or corrosive action on the material of the container and shall not pass from liquid phase to gaseous phase during testing, Ilie et al., 2014.

The pressure in the cylinder will have to increase gradually, continuously and without shocks (the pressure increase speed will not exceed 5 bar / minute). Seamless bottles will be kept at test pressure for 2 minutes and welded bottles for 5 minutes.

The testing facility shall be provided with two manometer connections. These will be fitted on three-way valves. The control gauge should be fitted to a fillet. The manometers used must be at least of the 2.5 precision class.

After the test pressure time has passed, carefully examine each cylinder.

The test shall be considered to be successful if no leakage, laceration or post-test are found and there are no deformations.

After the test, the pressure in the cylinders will gradually decrease without shocks, then the bottles will be completely emptied.

Cylinders with leakages, tears or deformations will be scrapped in such a way that they can no longer be put into circulation.

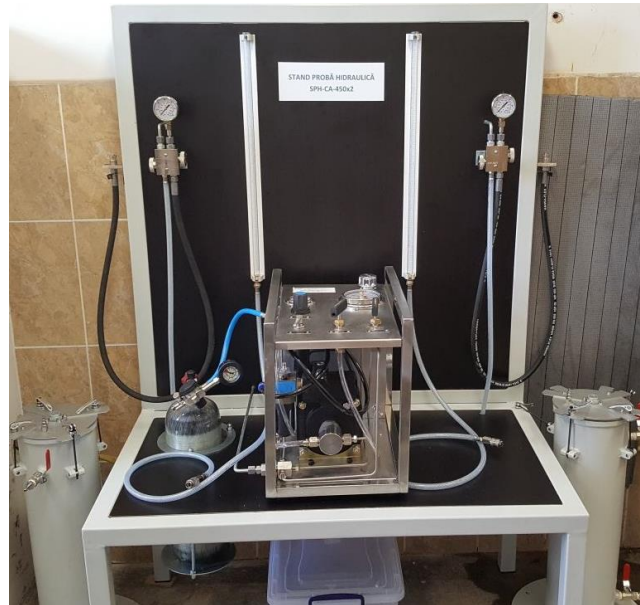


Fig. 2 Hydraulic pressure testing device

#### 4. Laser wave spectroscopy

Spectroscopy is a branch of physics that deals with the study of methods for obtaining spectra as well as measuring and interpreting them. The spectrum of an electromagnetic radiation is obtained by its decomposition into a spectral apparatus (spectrometer) and consists of a sequence of images of the input slot, formed by the different monochromatic radiation of incident light.

Spectroscopy uses spectral, photographic and photoelectric methods to study spectra. Depending on the spectral range of electromagnetic waves and equipment used, spectroscopy may be:

- optical spectroscopy (for visible, ultraviolet and infrared domains).
- X-ray spectroscopy, gamma-ray spectroscopy, Hertzian spectroscopy (for hertz and millimetric waves).
- alpha spectroscopy and beta spectroscopy deal with the study of energy spectra of alpha and beta radiation.

laser-induced decomposition spectroscopy is an optical emission technique that uses a laser to generate plasma. Spectroscopy provides a precise chemical composition and low detection limits (0.01 - 0.1%) because of argon purging. The precision and detection limits are improved by 10 times or more by purging with argon.

Laser waves Z analyse all types of alloys: steel, stainless steel, aluminium, copper, nickel, titanium, cobalt. Z waves spectroscopy boasts the best laser technology, it delivers high energy (5-6 mJ / pulse, 50 Hz) in one billionth of a second to generate gigawatt power densities - the key to a good plasma even and on the most refractory types of alloys.

The Z spectrometer is a portable analyser that uses LIBS spectroscopy (laser-induced breakdown spectroscopy), a type of atomic optical emission spectroscopy (OES). Since the beginning of the 19th century, scientists have known that the elements emit specific light colours. This colour combination represents a unique signature for each element. The wavelength (colour) of the specific lines reveals the present elements, and light intensity at a given wavelength is related to the concentration of each element.

The traditional OES technique used sparks and flames to generate plasma. Recent inventions and developments of laser technology, in turn, allow the use of lasers. This provides more precise control over plasma formation. Unlike sparks and flames, laser can generate plasma on the surface of non-conducting, unprepared samples such as soils, stones or liquids.

The portable LIBS spectrometer Z family ensures rapid and accurate identification and analysis of elements from hydrogen to uranium, depending on the selected model.

The three stages of the portable analysis using LIBS spectroscopy of samples are (fig. 3):

- generating plasma;
- light emission;
- light collection.

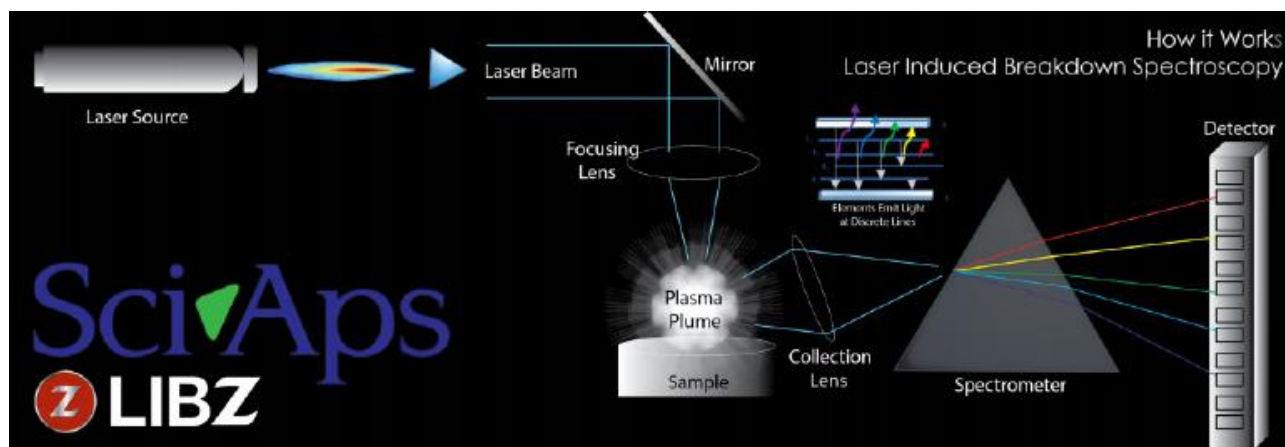


Fig. 3 stages of the portable analysis using LIBS spectroscopy of samples

The Z-300 Spectrometer (fig. 4) is the state-of-the-art LIBS portable analyser. Its advanced technology includes argon purge to provide quantitative results; the laser breaks the cleaned surface to the minimum grinding level or the prepared surface and performs the laser sweep for improved precision, reducing problems related to sample homogeneity.



Fig. 4 Z300 Spectrometer

Sample analysis using the Z laser wave portable spectrometer (fig. 5):

- A high-energy pulsed laser focuses on the sample. The high temperature of the laser on the sample leads to the removal of a small amount of material (about 0.002 inches: the thickness of a banknote) into the plasma wire. Plasma contains activated atoms and ions of the sample.
- As the plasma begins to cool, the electrons of activated atoms and ions return to their normal state. As they return to their normal state, the light of specific wavelength is emitted from the plasma and collected by the spectrometer.
- The spectrometer separates all light emitted by a high-resolution optic, detected by the charge coupled device.
- Elements detected in the sample can be viewed in a graph or in a spectrum. The graph represents the intensity of light emitted as a function of the wavelength.
- An embedded processor compares the height of specific peaks with a calibre. Calibres are built by testing a series of standards with known chemical composition. It provides quantitative chemical results.





Fig. 5 Sample analysis using the portable laser wave spectrometer Z

For most samples, their preparation is not necessary and they can be analysed as such. The Z-Spectrometer uses cleaning impulses to burn dust, surface dirt or other impurities. However, it is important to note that the LIBS technique is a surface measurement, and a layer of dirt or grease can influence the results, as surface elements will be analysed. If a sample is visibly dirty, the surface must be cleaned. If the surface is corroded or covered, the sample may be sanded to remove the corrosive or coating material.

Z Laser waves eliminate surface effects of the sample affecting other portable LIBS instruments. With Z, rarely a sample should be ground before analysis. The laser method of the Z analyser is triggered at 50 Hz (50 pulses / second) at a single location to burn sample contamination and dirt, over a period of 0.2 s, then collects spectral data for chemical analysis for 0.3 s. The laser is then automatically adjusted to repeat this process for multiple locations. The result is precise chemistry, repeatable after 1-2 seconds of testing. The sample cleaning and passivating patented combination of Z analyser eliminates variability from dirt or surface contamination.

To perform a test, the sample must be held in front of the analysis window in a straight (plane) position. The camera image can be used to ensure that the sample is straight with the front of the device and completely fills the laser slot. Once the sample is positioned correctly, press the Start button or the releaser. There will be a noise during the test and the plasma blinking in the device image will be visible. During the test, the screen will display chemical data. At the end of the test, the results screen will automatically open (fig. 6).

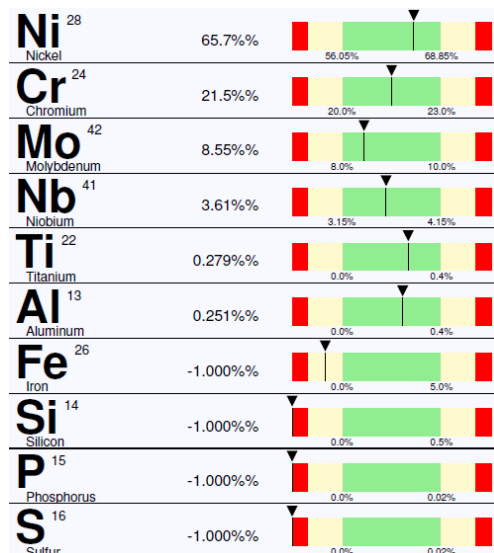


Fig. 6 Results testing using the laser wave spectrometer

## 5. Conclusions

Under pressure networks are represented by the following categories of installations and equipment: pipelines for gas, liquefied gases, pressurized gases, vapours and liquids, cylinder containers for under pressure compressed, liquefied or dissolved gases and stable under pressure metal containers, installed / fitted on foundations or other stationary stands or on moving platforms.

The steps to be taken in the technical control of under pressure networks are as follows: checking the general condition of the cylinders, external control, internal control, mass and capacity control, hydraulic pressure testing, leakage testing and pressure gauge testing using the laser portable spectrometer for metal analysis.

Spectroscopy is a branch of physics that deals with the study of methods for obtaining spectra as well as measuring and interpreting them. The spectrum of an electromagnetic radiation is obtained by its decomposition into a spectral apparatus (spectrometer) and consists of a sequence of images of the input slot, formed by the different monochromatic radiation of incident light.

The three stages of the portable analysis using LIBS spectroscopy of samples are: generating plasma, light emission, light collection.

Advantages of using laser-wave spectroscopy in the process of technical verification of pressure networks:

- simple and quick preparation of the test sample;
- quick and non-destructive multi-element analysis;
- the ability to provide an overview of unknown samples in a wide array of matrices.

This paper was developed within the Nucleu-Programme, carried out with the support of MCI, project no. PN 18 17 02 02 (Research on improving health and safety in hazardous environments with explosive, flammable and toxic atmospheres).

## **References**

- Technical Prescription PT C 5 - Technical requirements for the use of cylinders for compressed, liquefied or dissolved gases under pressure - Collection of State Inspection for Control of Boilers, Pressure Recipients and Lifting Installations - ISCIR, (2003).
- Technical Prescription PT C 4 - Stable metal pressure vessels - ISCIR, (2010).
- Technical Prescription PT C 6 - Pressurized metallic conduits for fluids - ISCIR, (2010).
- Technical Prescription PT C 10 - Steam pipelines and hot water pipelines - ISCIR, (2010).
- Ilie, C., Gaman, G.A., Pupazan, D., Calamar, A., Simion, S., Irimia, A., Research on technical inspection of cylinders filled with compressed gases, liquefied or dissolved under pressure using ultrasonic technology, Geoconference on nano, bio and green - technologies for a sustainable future, VOL I Book Series: International Multidisciplinary Scientific GeoConference-SGEM Pages: 165-171, ISSN: 1314-2704, (2014).

## Assessing the quality safety performance of the deflagration - detonating transient behavior specific to Class 1 hazardous materials, according to Orange Book

Daniela Carmen Rus\*, Emilian Ghicioi, Robert Laszlo, Cristian Radeanu, Attila Kovacs, Gabriel Vasilescu

National Institute for Research and Development in Mine Safety and Protection to Explosion – INSEMEX, 32-34 G-ral Vasile Milea street, Petroșani, 332047, Romania

---

### Abstract

Classification of products in different classes of the Orange Book is based on tests that are grouped into validated procedures and methods through series of tests that lead to the exact Class, Division, and Compatibility Group evaluation. "United Nations Recommendations" is an important global document on the transfer and movement of goods with different risks such as explosion, toxicity, radioactive contamination, chemical contamination, biological contamination, etc. Test kits designed to classify / verify the belonging of a substance as Class 1 (according to the United Nations Recommendations), i.e. explosive, provide clear evidence of classification, and their performance requires tests on significant quantities of materials to which they can find evidence of belonging to "Class 1 - Explosive".

*Keywords:* dangerous goods, transient behaviour, deflagrant-detonating

---

### 1. Introduction

Certain solid substances may have a specific behaviour with explosive stimuli of a detonating nature with restrictions on their transport and storage and the risk of explosion is one of the main industrial hazards in the economy, being present in all units producing, using, handling, storing and transporting solid substances with high level of danger. A chemical analysis in many situations can't provide a correct and complete assessment of the risks that may result from environmentally safe handling / transport / use / disposal, as the quantity of matter subject to expertise is determined in the sense of which the behaviour to external stimuli (of a thermal or mechanical shock) differs significantly depending on the diameter of the presumably explosive charge, the actual initiation capacity of the initiation means, the environmental factors, etc. Carrying out scale tests close to where solids accidents/disasters can occur in terms of detonation, stimulus behaviour and deflagration is essential in diagnosing/confirming risk class 1 classification under the United Nations Recommendations and which is useful for national authorities or other Member States to handle management of the transport and storage of these substances (Low no.126, 1995; Covello, V.T., et.al., 1993; ADR - European Agreement concerning the International Carriage of Dangerous Goods by Road, 2015; Cruz, M, 2004; ).

### 2. Experimental research on the study of the transition phenomenon from deflagration to detonation to various dangerous substances classified in Class 1 according to Orange Book

#### *a) Test on ammonium nitrate*

Ammonium Nitrate is classified either in Class 1 explosive materials with multiple UN numbers assigned or class 5.1. oxidising substances and in unusual class 9, as follows: (1) in class 1 is found at no. UN 0222 as ammonium nitrate containing more than 0,2% of combustible substances, including any organic material calculated on carbon, excluding any other additive; (2) in class 5.1. is found at no. UN 1942 as ammonium nitrate containing less than 0.2% combustible matter, including any organic material calculated in carbon, excluding any other additive. At no. UN 3375 can contain emulsions, gel or suspensions of ammonium nitrate in liquid or solid form (intermediate product for brighten explosives). As fertilizer based on ammonium nitrate we find products with no. UN 2067 Class 5.1. liquid ammonium nitrate in high concentrations (over 80% not more than 93%); (3) there are fertilizers containing ammonium nitrate in admixture with phosphates or potassium salts with an ammonium nitrate content up to 45% UN 2071 in Class 9 as recommended by the United Nations (DIRECTIVE 2014/28 / EU, 2014; ADR, 2015).

The United Nations Recommendations on the Transport of Dangerous Goods are based on a risk classification, with ammonium nitrate being classified in both Class 1 (Explosive) and Class 5 (Oxidising) and Class 9 respectively. Ammonium nitrate with high nitrogen content is found in Class 1 or Class 5.1 of danger according to its intended use, the manufacturing specification, the packing and storage mode with certain specified protective measures (figure 1).



Fig.1. Mounting for the test of porous ammonium nitrate

Porous ammonium nitrate was loaded into the trough (about 2100 g in the left side) in contact with the VUFL powder initiation portion (100 g portion right) initiation by firing flame open flame Bickford (figure 2).



Fig.2. The partial melting effect in the contact area between powder and ammonium nitrate tested

Burning of the powder used as an open fire source led to partial melting in the contact area between the powder and the experimental material (porous ammonium nitrate), without burning being maintained, the flame spontaneously extinguishing without a tendency for deflagration or detonation

#### *b) Test performed on an ANFO explosive*

The ANFO explosive is a mixture composed of porous ammonia granular porous with fuel oil / diesel fuel or other similar fuel, in compliance with Romanian legislation according to the Law 126/1995 on the regime of explosive materials with subsequent modifications and completions, as simplex mixtures classified in the class 1.5. ANFO is not itself flammable, but it can help combustion, even in the absence of air. When heated, it melts, and further heating may cause decomposition by releasing toxic vapours containing nitrogen oxides and ammonia vapours (figure 3), (DIRECTIVE 2014/28 / EU, 2014; ADR, 2015).



Fig.3 Test assembly for the ANFO type explosive

The ANFO explosive is packed in a bag and loaded into a primed gutter VUFL-type powder classified in class 1.3C (figure 4).



Fig.4 Flame with a tendency to maintain that led to burning a significant part of ANFO

In this case, the sample under test was more strongly affected by the source of initiation in the sense that the flame tended to maintain it, burning a significant portion of the sample to be tested and forming a crumb of molten and partially decomposed material in the flame contact area. Finally, the flame was extinguished by itself, a part of the load not visibly affected by the thermal effect of the fire. In this situation there is no question of analysing the phenomenon of transition from slow burning to violent deflagration or detonation.

#### *c) Test on explosive gel*

In order to perform this test, a hydrogel-type explosive for civil uses, supplied as 430 g cartridges, diameter 29 mm and length 550 mm, packed in plastic foil (figure 5), (DIRECTIVE 2014/28 / EU, 2014; ADR, 2015).





Fig.5 Explosion gel test assembly

The test explosive burnt fire with a slow propagation trend with total decomposition over time, without the phenomenon of passage from firing to violent deflagration or detonation.

### 3. Interpretation of results on the tendency of a substance to undergo the transition from deflagration to detonation, according to Orange Book

For Interpretation of results on the tendency of a substance to submit According to the Orange Book for Class 1 - Explosive, the test series 1-8 are applied depending on the nature of the substance, the presumed sensitivity to the different pulses that can initiate the product, de-flagrant or detonating. For Class 1 Explosives, the test series 1-8 are applied depending on the nature of the substance, the presumed sensitivity to the different impulses that can initiate the product, the deflagration or the detonating reaction. The test set out in Part 1 of the "Test Manual and Criteria" involves making assemblies in which a quantity of matter to be determined is placed and an external pulse, e.g. thermal shock or mechanical shock is applied. The attempt to determine the tendency of a substance to undergo the transition from deflagration to detonation is one of the primary attempts to accurately classify products of explosive nature for their classification in Division 1.5. Depending on the nature of the effects that can be obtained from the pilot tests, it can be concluded that their results are relevant, leading to the application of the whole mechanism involving additional tests provided by the Orange Book for accurate classification based on all criteria of the said document in classes / divisions and compatibility groups.

The results of the tests revealed the following:

- Test performed on an ANFO type explosive (figures 6, 7 and 8)



Fig.6 Complete assembly for performing the transition test from deflagration to detonation



Fig.7 The result of the test to deflate the test substance (ANFO)



Fig.8 The detonation effect of the detonating wound on the plate control (ANFO)

The result of this test to determine the trend of the ANFO substance to undergo the transition from deflagration to detonation was assessed, both in terms of examination of the blank plate surface, as a result of impregnation of the detonating wick on its surface as well as by the destruction of the detonating wick, agreeing that the tested ANFO substance tends to shift from deflagration to detonation.

-Testing on a METANIT explosive type (explosive anti-grit), (figures 9 and 10)



Fig.9 Location of the test assembly on the steel plate in the hopper



Fig. 10 Test result consisting of the detonation of the test substance highlighted by the destruction of the steel pipe

Testing of the explosive type Methanit (explosive classified as low power) highlighted the destruction of the steel pipe in the assembly and the confirmation of the detonating character of the tested material.

#### 4. Conclusions

The pilot tests highlighted in the paper concerned the behaviour of the manifestation of known / unknown fuel substances and the finding of their correct classification in class 1, division 1.5 according to the United Nations Recommendations; In this respect, the results of these tests highlighted the following: a) The test performed on an ANFO type explosive has demonstrated compliance with the United Nations Recommendations and validation of the correct pilot test. b) Testing of the explosive type Methanit (explosive classified as low power), intended for blasting under the risk of potentially explosive atmospheres, revealed the destruction of the steel pipe in the assembly and the unequivocal confirmation of the profoundly detonating nature of the tested material.

"The test for determining the tendency of a substance to undergo the transition from deflagration to detonation" is a very relevant way in determining the classification as "explosive product" in division 1.5, but insufficient for: a complete description of the mode of manifestation the risk of explosion, the probability of occurrence of the risky situation and the establishment of the technical measures that are necessary for their avoidance.

Implementation of the assembly "To undergo the transition from deflagration to detonation" is a development of the INCD INSEMEX Petroșani infrastructure for the application of the method of determining the sensitivity of solids, which is assumed to be a certain reactivity to external stimuli. Thus, the test itself is relevant to any solid matter, irrespective of granulometry or density, and is performed under the conditions specified in the United Nations Recommendations - Orange Book.

#### References

- Covello, V.T., Merkhofer, M.W., *Risk assessment methods. Approaches for assessing health and environmental risks*, Berlin-Heidelberg-New pringer, Berlin-Heidelberg-New York, (1993).
- Cruz, M., *Operational risk modelling and analysis. Theory and practice.*, published by Risk Book, a Division of Incisive Financial Publishing Ltd, London, (2004).
- DIRECTIVE 2014/28 / EU of the European Parliament and of the Council of 26 February 2014 on the approximation of the laws of the Member States relating to making available and checking explosives for civil uses.
- ADR - European Agreement concerning the International Carriage of Dangerous Goods by Road, Volume I, Edition 2015
- Recommendations on the Transport of Dangerous Goods, Manual of tests and Criteria, United Nations, New York Geneva, 2003.
- Low no.126 / 1995 on the regime of explosive materials with subsequent amendments and completions.

## Checking the quality of the electric igniter - pyrotechnic article of category P1, by laboratory methods applied to determine the sensitivity to electrostatic discharge

Edward Gheorghiosu<sup>a\*</sup>, Emilian Ghicioi<sup>a</sup>, Robert Laszlo<sup>a</sup>, Attila Kovacs<sup>a</sup>, Cristian Rădeanu<sup>a</sup>, Dan Gabor<sup>a</sup>

*<sup>a</sup>National Institute for Research and Development in Mine Safety and Protection to Explosion – INSEMEX Petroșani, 32-34 G-ral. Vasile Milea Street, 332047 Petroșani, Romania*

### Abstract

Pyrotechnic article are means of any article containing explosive substances or an explosive mixture of substances designed to produce heat, light, sound, gas or smoke or a combination of such effects through self-sustained exothermic chemical reactions.

In this generic term "Pyrotechnic articles", includes fireworks, means a pyrotechnic article intended for entertainment purposes (F 1, 2, 3, 4), theatrical pyrotechnic articles, means pyrotechnic articles designed for indoor or outdoor stage use, including movies and television productions or similar use (categories T1 / T2) and pyrotechnic articles (categories P1 / P2) used for technical purposes or as means of initiating fireworks.

In the category of pyrotechnic articles are classified "Electric Igniter", used as means of ignition of pyrotechnic articles of entertainment, theatrical or technical application.

Electric current is used to heat a resistive element (bridge wire) of this product. The sensitive pyrotechnic composition in contact with the bridge wire is ignited by heat transfer generating a fire with transferable energy.

Burning of the pyrotechnic composition of electric igniter, initiating the fireworks, theatrical pyrotechnic articles or technical pyrotechnic articles.

In order to be used for the purpose for which it was designed, the electric igniter must meet certain operating and safety requirements.

One main security parameter to be checked at the electric igniter is the sensitivity to electrostatic discharges.

This paper presents the results and conclusions obtained in the laboratory tests applying a test method to different configurations to determine this security and the level of this quality parameter.

**Keywords:** pyrotechnic articles, electric igniters, electrostatic discharge, method for testing, quality assurance;

### 1. Introduction

The electric igniters are pyrotechnic articles for the electrical initiation (ignition) of other pyrotechnic articles (theatrical pyrotechnic articles of category T1 or T2 or fireworks of category FI, F2, F3 or F4), (Fig.1), Gheorghiosu et al, 2012.

The electric igniters have a pyrotechnic composition crossed by a nickel filament which has the role of an incandescent electrical resistance.



Fig. 1. Electric igniter;

The filament is powered by voltage through two copper insulated conductors with lengths of 2 m.

\* Corresponding author. Tel.: +4 0731 320757; fax: +4 / 0254 541561.  
E-mail address: edward.gheorghiosu@insemex.ro

The pyrotechnic-filament composition can be protected with a plastic sleeve that has the role of protection against mechanical actions but also to direct forward the flame produced by the burner. (Fig.2.)



Fig. 2. Electric igniter with plastic sleeve;

The protective sleeve can be removed when necessary but only before use and taking into account that the inflammatory pyrotechnic is very sensitive to mechanical action, friction and static electricity (especially when it is already connected to the firing line). (Fig.3).



Fig. 3. Electric igniter with plastic sleeve;

#### 1.1. Technical characteristics of electric igniters:

- Fire current: 0,5A.
- Safety current: 0,25A 5s/ 0,18A 5s.
- Resistance:  $2 \pm 0,2 \Omega$ .
- Leg wires of copper with length 2000 mm, PVC.
- Initiation time: 20÷70 ms;

#### 1.2. Description of method for determination resistance to electrostatic discharge (ESD), SR EN 16265:2015

This test aims at determining whether electric igniters can withstand an electrostatic discharge (ESD) without initiating. (Directive 2013/29/EU) This test should not be undertaken on magnetically-coupled igniters.

For electric igniters with a sole central pin and a casing which acts as second pin, only the “pin-to-pin” configuration shall be taken into consideration, Ghicioi et al, 2012.

For electric igniters where the sensitive element is only protected by a varnish or by a non-metallic protection (Fig.2), the “pin-to-case” configuration corresponds to the application of ESD between the two short-circuited leading wires and a conductive electrode through the protection. (Fig.4)

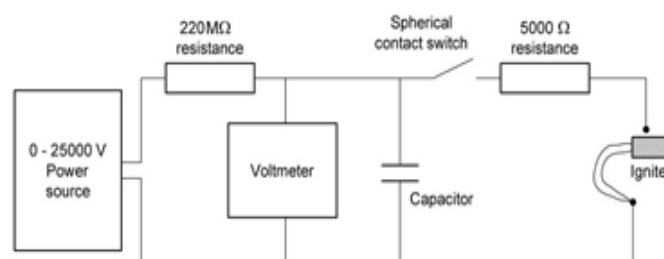


Fig. 4. Schematic of assembly the ESD test circuit;

Apparatus, ESD generator Electrostatic discharge generator with capacitance ranging from 500 pF to 3500 pF and sufficient voltage to give the required impulse.

Preparation of the test:

The samples must be having the same design and construction of the fusehead and the leading wires, in the case of leading wires, they shall have the same length ( $\pm 0,05$  m);

Then ensure that the leading wires and all measuring equipment are kept in the same position as they were when adjusting the ESD generator;

The ESD impulse to be applied to the igniter shall be in accordance with the requirements, if no-fire current ( $I_{NF}$ ) is  $0,15 \leq I_{NF} < 0,25$ , the minimum ESD impulse must be  $0,2 \text{ mJ}/\Omega$  for the "pin-to-pin" configuration and  $0,2 \text{ mJ}/\Omega$  for the "pin-to-case" configuration.

The test carry out at  $(20 \pm 5,0) ^\circ\text{C}$  and at a relative humidity not greater than 60 %;

The leading wires and cables (if any) are kept at a distance of at least 100 mm from the ground and from any conductive objects that might cause leakage paths to earth;

For "pin-to-pin" configuration, must be apply the ESD between the two separate ends of the leading wires or between the two pins.

Must be repeat the operation 5 times successively for each igniter, allowing at least 10 s between each pulse;

For pin-to-case configuration twist together the ends of the two leading wires and apply the ESD between the twisted ends of the leading wires or between one of the two pins and the casing of the igniter.

Must be repeat the operation 5 times successively for each igniter, allowing at least 10 s between each pulse.

## 2. Results and comments

Table 1. Results of tests "pin-to-pin" configuration (I-initiation, N-no initiation)

Test conditions	No. test													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Temperature: $19^\circ\text{C}$	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Relative umidity: 46%														

By applying the configuration, it was obtained the ensemble from figure 5.

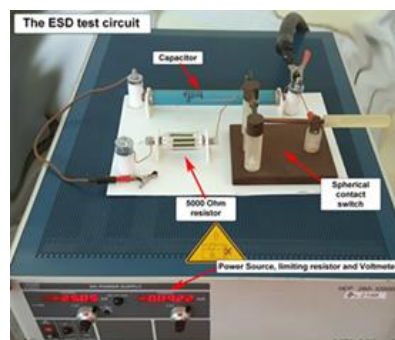


Fig. 5. Stand for testing;

It have been performed 28 tests on electrical igniters in two "pin-to-case" configuration.

The first configuration, a 5 mm wide circular electrode was positioned in the middle of the plastic guard. (Fig.6)



Fig. 6. The electrode positioned in the middle of the plastic guard

Table 2. Results of tests "pin-to-case" configuration (I-initiation, N-no initiation)

Test conditions	No. test													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Temperature: $19^\circ\text{C}$	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Relative umidity: 46%														

The second configuration, a 5 mm wide circular electrode was positioned at the end of the plastic guard. (Fig.7)

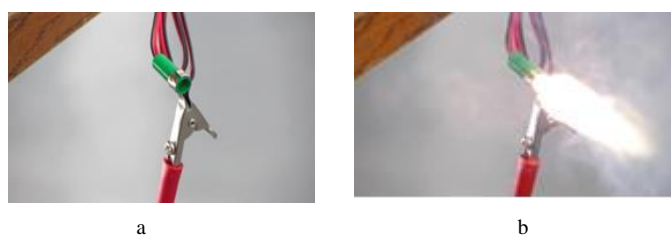


Fig. 7. (a) The electrode positioned at the end of the plastic guard; (b) Initiation electrical igniter

Table 3. Results of tests "pin-to-case" configuration (I-initiation, N-no initiation)

Test conditions	No. test													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Temperature: 19 <sup>0</sup> C	I	I	I	I	I	I	I	I	I	I	I	I	I	I
Relative umidity: 46%														

### 3. Conclusions:

The electrostatic discharge test (ESD) is a safety parameter of this type of pyrotechnic article.

To perform the tests, an important technical detail is the method of fixing the electrodes to the electrical igniters.

The most severe test condition must be identified to verify the compliance of the initiators with the safety requirements.

If this principle is not applied the electrical igniters that do not have security in use can be used which can lead to major accidents.

INSEMEX Petrosani has implemented this test method thus developing the expertise / test capacity to check these types of products in the process of certification and technical expertise.

### Acknowledgements

Project EXTTOX, PN 18 17 01 01 - Develop the institutional capacity for technical expertise of explosion / fire events.

### References

- Gheorghiosu E., Kovacs A., Rus D., C., Bordoş S., *Development of the testing infrastructure for verification of fireworks categories 1,2,3*, Environmental Engineering and Management Journal (EEMJ), Volume 11, Issue 7, Pages 1287-1290, Published Jul. 2012.
- SR EN 16265 - *Pyrotechnic articles- Other pyrotechnic articles - Ignition devices*
- Directive 2013/29/EU of the european parliament and of the council of 12 June 2013 on the harmonisation of the laws of the Member States relating to the making available on the market of pyrotechnic articles.
- Gheorghiosu E., Ghicioi E., Kovacs A., Vasilescu G., Rus D., *Determination of the delay accuracy of the components of non-electric initiation systems*, Environmental Engineering and Management Journal, Volume: 16, Issue: 6, Pages: 1283-1287, Published: JUN 2017.
- Ghicioi E., Pârăian M., Lupu L., Jurca A., *A new method for verification of ignition systems integred in special trucks*, Environmental Engineering and Management Journal (EEMJ), Volume 11, Issue 7, 2012.



# Computational simulations of the transport and ignition of methane in enclosed spaces

Gheorghe-Daniel Florea<sup>a\*</sup>, Nicolae-Ioan Vlasin<sup>a</sup>, Zoltan Vass<sup>a</sup>,  
Adrian Bogdan Șimon<sup>a</sup>, Ligia Ioana Tuhuț<sup>a</sup>

*<sup>a</sup>National Institute for Research and Development in Mine Safety and Protection to Explosion - INSEMEX, 32-34 G-ral Vasile Milea Street, 332047  
Petrosani, Romania*

---

## Abstract

Most of the time, in assessing a situation where a leakage of combustible gas is involved, the volume of the room where the release occurs and the volume of the released gas is taking in account, thus resulting in an average concentration of the fuel gas applied to the entire volume of the room. This paper explores the release of methane gas inside a closed space and the initiation of the mixture at different concentrations reached at the spark location. The experiments are virtually performed through CFD techniques. As a result of virtual tests, differences were observed between the simulation results and the calculation currently used for the determination of methane concentrations in enclosed spaces in case of accidental leakages of combustible gases.

*Keywords:* leakage; methane explosion; CFD; computational simulation; methane ignition.

---

## 1. Introduction

A leak or a break in a pipeline is a result of failure of a defect in the pipe wall. Failure of an existing defect may occur as a result of change in load level, dynamic events, defect growth (for example, fatigue, corrosion), or diminishing material toughness (for example, temperature drop, aging) (Cioca, L.I et al., 2012; Pasculescu D. et al., 2012).

Most often, investigating an explosion due to a leakage of fuel gas takes into account the volume of hazardous gas relative to the volume of the space where the leakage occurred, considering the uniformity of gas concentrations in volume (Beveridge A. 2011). But the problem is much more complex.

Firstly, the transport of the fuel gas is based on the pressure gradients generated by the gas pressure in the pipe. Then there is an expansion of the gas, a shift from a higher density to a lower one. When the gas passes through the leakage hole, its temperature decreases, and then, when released into the room volume, a heat transfer takes place between the gas and the inner atmosphere. Also, a larger hole in the pipe provides a greater area over which the pressure can act (Maria P. et al., 2016). The hazard radius is defined as the largest horizontal extent of the hazardous area generated by a leak when situated in an open area (Cleaver R.P et al., 2011).

Even if all of these calculations were made with the utmost precision, locating the cloud of fuel gas and spreading it in to space would remain unknown. Existence of airflow in the room and walls temperatures are other factors to be considered.

The location of the ignition source versus the leakage location has a great importance. Immediate ignition can be considered as the situation where the flammable gases are ignited immediately after leakage accidents by auto-ignition or accident ignition source. Delayed ignition is the result that the release and diffusing flammable gas cloud is ignited by other ignition sources apart from the release point (Changlong Z. et al., 2012).

Therefore, using CFD tools makes a considerable contribution to this domain. With some approximation, these techniques can predict the behavior of the fuel cloud, the way in which initiation of the formed explosive atmosphere

---

\* Corresponding author. Tel.: +40 799 211 677  
E-mail address: daniel.florea@insemex.ro

and the development of the explosion takes place. These approximations can be of real use in the explosion risk assessment and decision-making process regarding the necessary safety measures.

## 2. Setting the computational domain

All the virtual activities, including geometry construction, meshing, setting the boundary conditions, solving and post-processing were performed in ANSYS Multiphysics package. ANSYS Fluent was used to define the domain properties and calculate the results. The Fluent application is based on finite volume method and can perform 2D and 3D simulations of various types of problems including multi-component and multi-phase flows, compressible flows, flows with heat transfer, cavitation and other phenomena.

### 2.1. Geometry and meshing

The virtual geometry consists of a rectangular tube of dimensions 500 x 50 x 50 mm (Fig. 1.). One of the ends of the tube is closed and the other end has a 10 x 10 mm hole in the center, to release the explosion pressure. The inlet of the gas in the tube is located on the lower surface of the tube at a horizontal distance of 100 mm from the closed end, on a central-longitudinal line of that surface. The inlet is circular and has a diameter of 5 mm. The spark location is in the middle of the closed end of the tube.

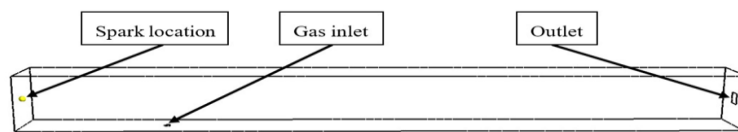


Fig. 1. Rectangle tube with locations of the spark, inlet and outlet

The meshing process used the Proximity and Curvature Size Function, with Fine option for Relevance Center and a maximum Face Size of 3 mm. This resulted in a number of 407884 tetrahedrons and 74610 nodes. Fig. 2. shows the finite volumes, in a 3D representation, which compose the mesh of the tube sectioned by a vertical plane.

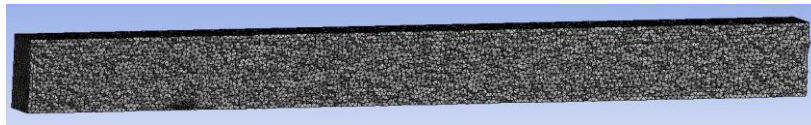


Fig. 2. Discretized geometry

The refined mesh in the proximity of the gas inlet can be seen on the lower surface of the tube. This refining is needed to improve the realism of releasing methane gas into the analyzed space. Fluent application is sensible to the mesh quality. One of the rules of thumb is that the skewness must be below the value of 0.98. Also, the orthogonal quality is a very important factor. When in Fluent, it is necessary to check and report the quality of the mesh.

### 2.2. Domain setup

Considering the target objectives: transport and ignition of the air-methane mixture at different concentrations obtained at the spark location, the problem was defined as a transient case, density-based, with gravitational acceleration activated.  $k-\epsilon$  turbulence model was used with Viscous Heating, Buoyancy Effects and Curvature Correction options checked.

The gas inlet was set as a pressure inlet, inducing a pressure of 103325 Pa, 2000 Pa above the rest of the domain and a temperature of 293 K. Through this surface, the methane enters into domain at unity mole fraction.

The outlet – the hole to release explosion pressure – was set as pressure outlet with an atmospheric pressure on its surface (101325 Pa), and oxygen of 0.2091 mole fraction at a temperature of 293 K.

The other sides of the rectangular tube were defined as walls with the same temperature as the outlet and inlet.

Species Transport was selected for the species model. The air-methane mixture was set as compressible gas (ideal-gas in Fluent application). During the simulation, for compressible ideal gas, ANSYS Fluent calculates the static temperature on the inlet surface based on the enthalpy, which is determined by the total temperature declared as the boundary condition.

The reaction mechanism consists of the stoichiometric reaction of the methane oxidation, from the materials database of application.

The entire domain was set at a temperature of 293 K, a pressure of 101325 Pa and a clean atmosphere (0.2091 oxygen mole fraction).



### 3. Computational simulations

In order to initiate the explosive atmosphere created inside the tube, a first simulation monitored the increase in methane concentration at the spark location and the average methane concentration on a vertical plane that centrally divides the tube. Thus, at the level of the spark location it was possible to determine the times at which the methane concentrations were in the explosive area, between 5 and 15% vol. CH<sub>4</sub> (Fig. 3.).

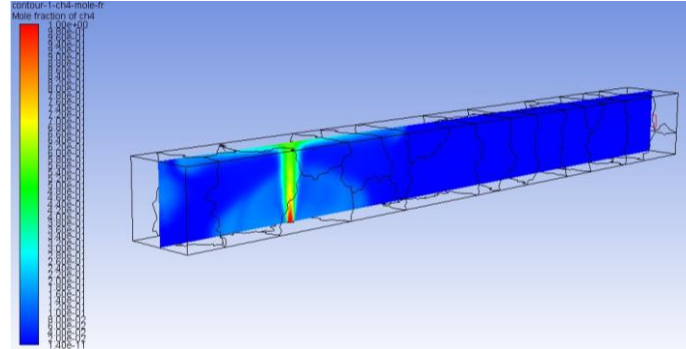


Fig. 3. Monitoring of the molar fractions at the spark location and on the vertical plane

The increase in methane concentrations is shown in Fig. 4. The volumetric methane concentration (% vol. CH<sub>4</sub>) is 100 times the mole fraction.

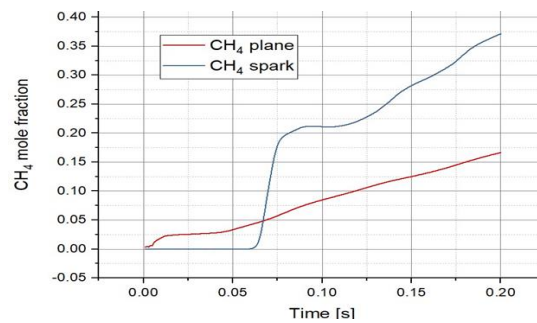


Fig. 4. Mole fractions at the spark location and on the vertical plane

Hence, the relevant data of the passage of methane concentration through the explosive area was obtained for the sparking location, data included in Table 1.

Table 1. CH<sub>4</sub> mole fraction at spark location

Case No.	Timestep No.	Time [s]	CH <sub>4</sub> mole fraction
1	67	0.067	0.048913
2	68	0.068	0.067778
3	69	0.069	0.086641
4	70	0.070	0.104969
5	71	0.071	0.122878
6	72	0.072	0.140154
7	73	0.073	0.155635

The time step used for this first simulation was of 0.001 s. In order for the simulation to be resumed from each concentration of CH<sub>4</sub> contained in Table 1, the associated data files were written at each timestep. This was done because the simulations of the gas explosions require a smaller timestep.

For the 7 computational simulations related to the 7 timesteps in Table 1, the activation moments were set for the spark located in the center of the closed end of the tube. For each simulation, the spark activation time was set to 0.0005 s from the start of the simulation and the timestep was set to 0.0001 s.

At the spark location, concentrations of methane, oxygen and reaction products (carbon dioxide and water), as well as temperature, were monitored. The ignition of the air-methane mixture occurred in each case, even when the methane concentration exceeded the explosive concentration at the spark location.

Fig.5. shows a series of images of the methane released inside the tube, ignition and performing of the simulated explosion.

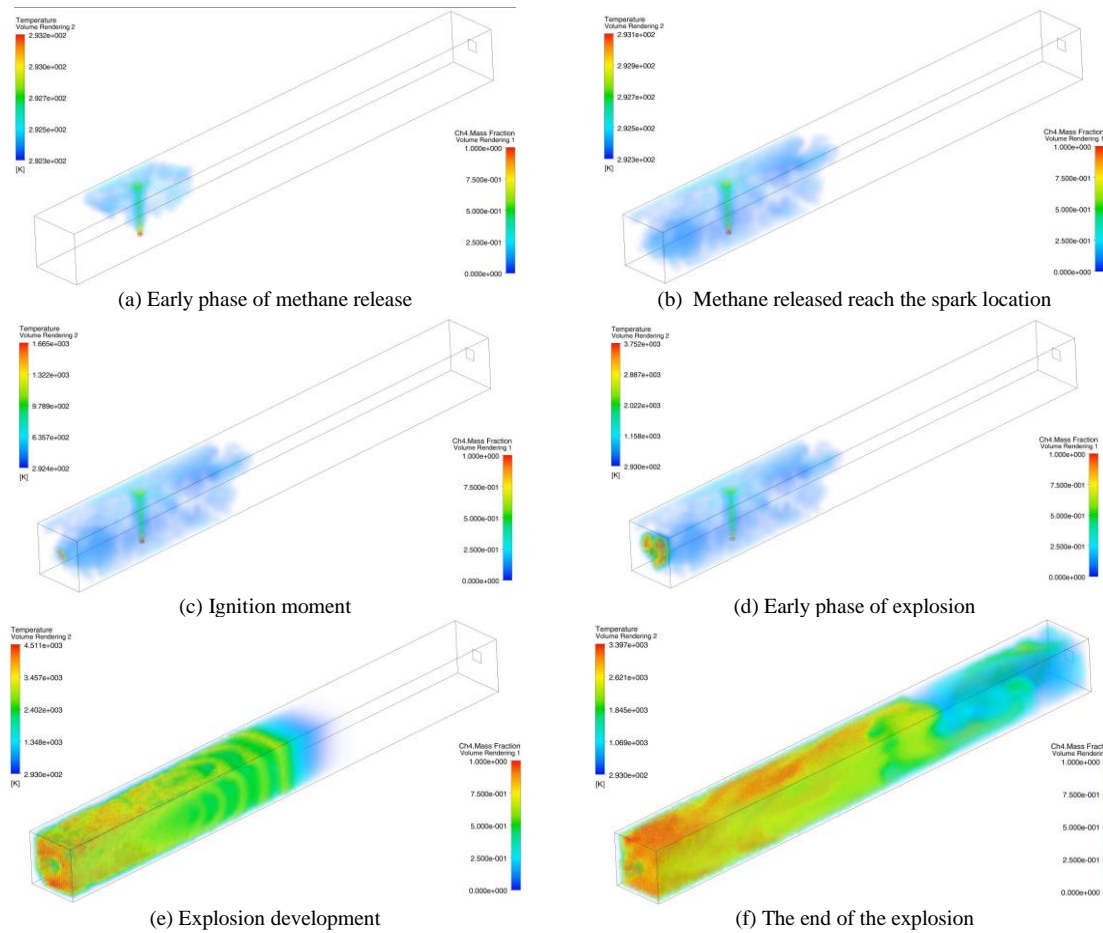


Fig. 5. Series of images of released methane, ignition and simulated explosion

#### 4. Results

In each of the seven simulations, the explosion of the air-methane mixture inside the rectangular tube occurred.

The spark was activated at 0.0005 s from the start time of the simulation for each case, so the exact methane concentrations at the spark location were known only after the simulations run. The times and methane concentrations at which the spark has been activated for the seven cases are listed in Table 2.

Considering the piston effect, the methane in front of the flame was pushed beyond the expansion limit of the release phase so that the flame front advanced, in all cases, close to the explosion pressure outlet.

An interesting case is the last one, where the concentration of methane at the spark location exceeds the limit of explosivity, however the ignition takes place. The case deserves attention, which is why it is discussed below.

Table 2. CH<sub>4</sub> mole fraction at the moment of spark activation, for each case

Case No.	Spark time [s]	CH <sub>4</sub> mole fraction at the moment of spark activation
1	0.0675	0.054938
2	0.0685	0.074143
3	0.0695	0.092692
4	0.0705	0.110656
5	0.0715	0.128261
6	0.0725	0.144991
7	0.0735	0.159692

The decrease, by burning, of methane mole fraction at the spark location and after the spark activation, for the seven cases, is shown in Fig. 6.

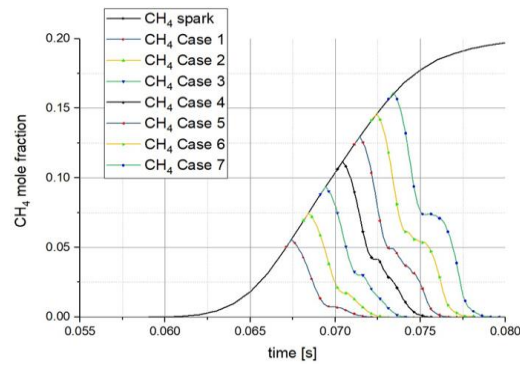


Fig. 6. Mole fractions at the spark location and on the vertical plane

## 5. Discussion

The most interesting case is the last one, where the ignition takes place at a methane concentration that exceeds the upper limit of explosivity at the spark location. This is why the case has been analyzed in detail, noting what is happening in the proximity of this location.

To analyze the situation, the charts of reactants and reaction products evolution during the process, as well as of the temperature at the location of the spark and the maximum temperature over entire volume were built (Fig.7.).

As can be seen from the figure, the temperatures at the spark location and the maximum recorded inside the volume increase at the same time up to a point where the methane concentration is already in the explosive area. After this moment, the maximum temperature inside the volume shows a higher growth rate.

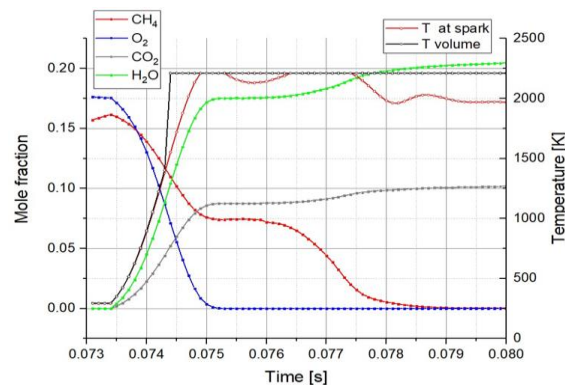


Fig. 7. Case 7. The evolution of the reactants, reaction products and temperatures at spark location and inside the volume

This can be interpreted as a movement of the reaction from the spark location, also motivated by the low oxygen concentration in that place at that moment. In order to have a comparison term, a graph was created with the values recorded in case 3 (Fig. 8.).

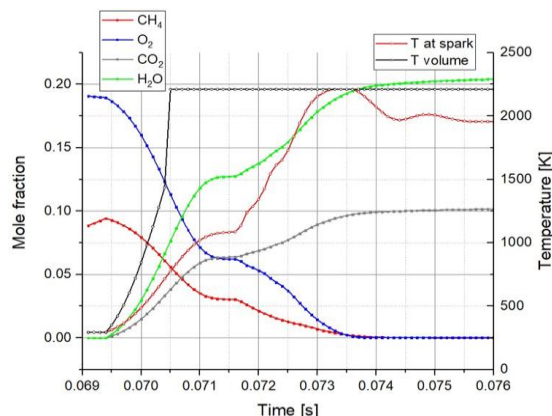


Fig. 8. Case 3. The evolution of the reactants, reaction products and temperatures at spark location and inside the volume

By comparison between the two cases, a totally different behavior of the evolution of the reactants, the reaction products and the temperatures can be observed. For the temperatures in Fig. 8, the curves are separated immediately after the moment of spark activation, which indicates a faster movement of the flame from the spark location.

For Case 7, the moment of separation of the two temperature curves (spark location temperature and the maximum temperature over the volume of the tube) is shown in Fig. 9. At this moment, the flame is out of spark location.

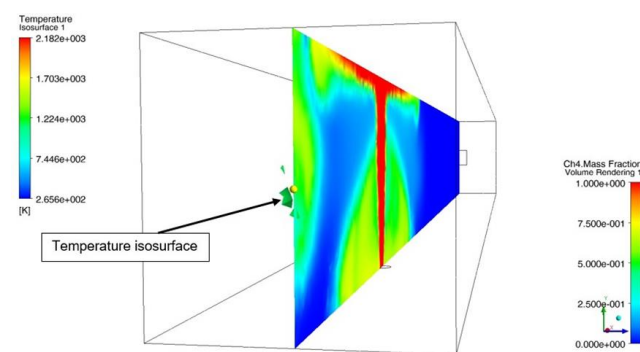


Fig. 9. The moment of separation of the two temperature curves for Case 7

## 6. Conclusions

Analyzing Fig. 4, it can be seen that at a concentration of approx. 15% vol.  $\text{CH}_4$  at the spark location corresponds to a methane concentration of more than 30% vol. at plan level, which would produce an erroneous analysis by the usual calculations.

When a volume of methane is released in a larger volume of air, a non-homogeneous air-methane mixture forms. In this case the initiation of the mixture may occur even if at the spark location the methane concentration exceeds the explosive area, by a local burning of methane and a contribution of oxygen from areas with clean air. However, this possibility of initiation requires further research, by conducting physical experiments and obtaining edifying records.

## Acknowledgements

This paper was developed within the Nucleu-Programme, carried out with the support of Romanian Ministry of Research and Innovation, project no. PN-18-17-01-01, project title: Developing the institutional capacity for performing technical investigation of explosion/fire type events (in Romanian: Dezvoltarea capacității instituționale pentru realizarea expertizelor tehnice ale evenimentelor de tip explozie/incendiu).

## References

- Beveridge, A. Forensic Investigation of Explosions, Second Edition, CRC Press, p.353, (2011).
- Cioca, L.I.; Moraru R.I.; Babut, G.B. A Framework for Organizational Characteristic Assessment and their Influences on Safety and Health at Work, Proceedings of the 15th International Conference on the Knowledge-Based Organization: Management, Book Series: Knowledge Based Organization International Conference, Volume: 2, Sibiu, Romania, pp. 43-48. (2009).
- Changlong, Z.; Juncheng, J.; Xiongjun, Y. Study on ignition probability of flammable materials after leakage accidents, Procedia Engineering 45, Published by Elsevier Ltd., pp. 435-441, (2012).
- Cleaver, R.P.; Cumber, P.S. A method for assessing the consequences of small leaks in enclosures, Published as IChemE Symposium series no. 148, pp. 503-516, (2011).
- Pasulescu, D.; Lupu, L.; Pasulescu, V.; Inisconi, I.; Suvar, M. Study of electrocution hazards in three-phase electrical networks with ground-isolated neutral point, Environmental Engineering and Management Journal, Volume 11, pp. 1267-1271, (2012).
- Prodan M., Ghiciei E. Nălboc.I, Szollosi-Mota. A. Minimum ignition temperature of dust cloud analysis for safe industrial processes, 7 th International Multidisciplinary Symposium "Universitaria Simpro 2016" -7th Edition Petroșani Romania, pp 199-244, (2016).

ANSYS Fluent User's Guide.

## Determination of flammability parameters and burning gases, in order to reduce risks in the fire or explosion type events

Szollosi-Moța Andrei\*, Ghicioi Emilian, Prodan Maria, Nălboc Irina, Șuvar Sonia

*National Institute for Research and Development in Mine Safety and Protection to Explosion – INSEMEX, 32-34 G-ral Vasile Milea street, Petroșani, 332047, Romania*

---

### Abstract

The study of the characteristics of fires or explosions, as well as factors influencing their production and development, leads to the increase of the fire / explosion expertise capacity, the expansion of the knowledge field related to these phenomena, also increasing the health and safety at work. Because of the random evolution, there cannot be two fires the same. A number of factors are involved in the development of a fire: the nature and positioning of combustible materials, the shape and dimensions of the room, the thermal load, the openings to the outside, the location and mode of initiation of fires, etc. Following the similarity of these numerous factors, fire experiments on a natural scale produce very varied results. For the study and experimental determination of the flammability parameters of the different materials and the assessment of the fire behaviour, the following were made: the stand for vertical and horizontal burning determination according to SR EN 60695-11-10, the stand for determination of the ingress efficiency SR 652: 2009. Experimental determinations were performed with these stands.

Also, the evolution of the concentration of the most significant gaseous effluents over time has been studied: carbon dioxide, hydrogen cyanide, nitrogen oxides, etc. Different polymeric materials such as polymethylmethacrylate, rubber, melamine was taken in consideration to study the nature and concentration of gaseous effluents.

As a result of the combustion of the polymeric materials, high concentrations of gases with high toxicity, namely: carbon dioxide, hydrogen cyanide, nitrogen oxides, and the distribution of these concentrations were determined during the tests. The nature of the resulting gas is dependent on the composition of the burning material, such as for example burning melamine, resulting in significant amounts of hydrogen cyanide.

*Keywords:* fire, toxic gaseous, flammability

---

### 1. Introduction

Combustion processes are oxidation reactions of some substances, resulting in different amounts of heat. For the complete oxidation of combustible elements, a minimum amount of oxygen is contained in a minimum amount of air. Combustion carried out in the presence of the minimum required air is called stoichiometric burning or theoretical combustion. Incomplete combustion processes result in significant amounts of carbon dioxide. Calamar et al. 2017.

The main gases of toxic, asphyxiating, irritant, flammable nature, etc., that can be generated from fires / explosions are:

CO<sub>2</sub>-carbon dioxide and CO-carbon monoxide are common combustion product and significant amounts of

HCl - hydrochloric acid, is generated by the combustion of polyvinylchloride and chlorine-protected synthetic materials (chlorinated polyesters);

HCN - hydrogen cyanide is released from polyamides, polyacrylonitrile, polyurethane, polybutadiene, polystyrene and nitrate polymers, for example, polyurethane releases the highest amount of HCN at temperatures of about 1000 ° C, HF - hydrofluoric acid is released in the case of polytetrafluoroethylene. Strec A.A. et al., 2008.

NO<sub>x</sub> (N<sub>2</sub>O, NO, NO<sub>2</sub>) is released by burning polyacrylonitrile, polyamide and cellulose, styrene

---

\* Corresponding author: tel +40740242975  
E-mail address: andrei.szollosi@insemex.ro

NH<sub>3</sub> - ammonia, is an irritant gas; in the case polyamide combustion has a maximum permissible concentration of 50 ppm, incomplete combustion products such as tar, aliphatic or aromatic hydrocarbons in the form of very fine particles / aerosols, which can cause bronchial / pulmonary damage. Gann et. al. (2010)

Smoke combustion products are fatal to a large extent because in their presence people become disoriented, suffer respiratory disturbances, lose their knowledge and physical mobility. After a period of hyperventilation of the body, as a result of inhalation of irritant gases, the main causes leading to death are the inhalation of carbon monoxide (CO) and hot gases. Abdulrhmann, 2015.

The most significant toxic effluents from common fires are: carbon monoxide (CO), hydrogen cyanide (HCN), carbon dioxide (CO<sub>2</sub>), hydrochloric acid (HCl) and nitrogen dioxide (NO<sub>2</sub>). Carbon monoxide is considered the most dangerous toxic gas because it can be found in large quantities at all fires. The importance of each toxic gas for a specific fire must reflect both its toxicity and the concentration in which it forms. Exposure time is also important for determining the effects of toxic gases. Carloganu, 1986.

Risks / hazards may increase / may become greater when the listed substances react with each other or react with other substances.

## **2. Determination of flame propagation testing methods and results**

Determination of the flame propagation in the vertical plane for cables can be made by optical cables according to the European standard IEC 60332-1 (3), thus the method of testing the burning rate of the plastic materials from which the cable sheath is made. Fire hazard tests (SR EN 60695-11-10) Part 11-10: Test flames.

Horizontal and vertical flame test methods Horizontal and vertical flame test methods of 50W flame are based on the fixation of the test specimen horizontally and vertically, determining the vertical and horizontal firing rates. The test or preconditioning test leads for 8 hours at 70 ° C. Test specimens have a size of 125mm ± 5mm. Diameters used for testing: 8mm and 4mm. Or conditioning two sets of test materials at 23 ° C, they were marked at a distance of 25mm from the longitudinal axis. The flame burner is applied for 10 seconds or removed if the flame front exceeds the 25mm mark.

Smoke combustion products are fatal to a large extent because in their presence people become disoriented, suffer respiratory disturbances, lose their knowledge and physical mobility. After a period of hyperventilation of the body, as a result of inhalation of irritant gases, the main causes leading to death are the inhalation of carbon monoxide (CO) and hot gases. Szollosi-Mota et.al. (2018)

The test method was developed in accordance with SR EN 60695-11-10 Part 11-10: Test flames.



Fig.1 Testing of flame propagation velocity



Table.1 Determination of horizontal flame propagation velocity for cable 4mm diameter

Type of cable	Time at which the flames were applied [s]	Flame propagation rate [mm]	Flame propagation velocity [mm/min]	Average propagation velocity [mm/min]
Cable diameter 4mm	30	8	16	9,6
		10	20	
		10	20	
		9	18	
		7	14	
		11	22	
		12	24	
		10	20	
		9	9	
		10	10	

Table. 2 Determination of horizontal flame propagation velocity for cable 8mm diameter

Type of cable	Time at which the flames were applied [s]	Flame propagation rate [mm]	Propagation velocity [mm/min]	Average propagation velocity [mm/min]
Cable diameter 8mm	30	7	14	12,6
		8	16	
		6	12	
		5	10	
		6	12	
		5	10	
		6	12	
		7	14	
		8	8	
		5	10	

Testing was performed on test specimens on two types of cables with test diameters of 4 and 8 mm. The test tubes have a size of  $125 \text{ mm} \pm 5 \text{ mm}$ . Diameters used for testing: 8mm and 4mm. A timer was used to measure the flame time. Two sets of test materials were conditioned at  $23^{\circ}\text{C}$ , they were marked at a distance of 25mm from the longitudinal axis. The flame burner is applied for 10 seconds or removed if the flame front exceeds the 25mm mark.

Table 3 Determination of vertical flame propagation velocity for cable 8mm diameter

Type of cable	Time at which the flames were applied [s]	Length of burned cable [mm]	Propagation velocity [mm/min]	Average of propagation velocity [mm/min]
Cable diameter 8mm	10	20	120	109,6
		18	108	
		16	96	
		18	108	
		18	108	
		17	102	
		18	108	
		19	114	
		20	120	
		19	114	

### 3. Method of determining flame-resistance and results

Determination of flame-retardant efficiency: SR 652: 2009 Wood, plywood, chipboard, wood fibre boards. Considering the parameters described in the standard, a test stand was carried out by a method of laboratory determination of the effectiveness of flame retardant products applied on wood, plywood, chipboard. The test consists in determining the mass loss of flameproof specimens subjected to combustion. After the burner gas supply is interrupted, determine the duration of residual flame or residual incandescence. The test method is based on determining the mass loss of flame retardant specimens subjected to combustion.



Fig.2 Testing of flame resistance

Table 4 Determination of flame retardant efficiency

Type of tested material	Loss of the specimen [%]	Thickness of specimens [mm]	Application time of flame [min]
Woods chips plates	24,88	10	15
Pal plates	13,24	15	15
Pal laminated plates	14,71	16	15
Plywood non-fire resisting	66,19	0,5	15
Slim plywood	73,99	0,3	15

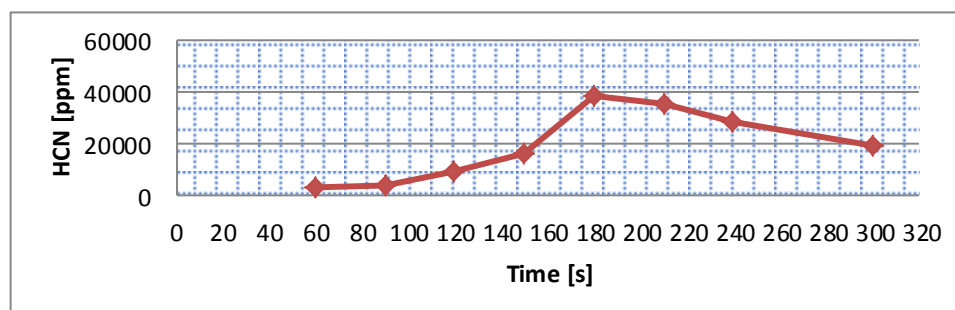


Fig. 3 Variation of concentration of hydrogen cyanide in time in the burning of melamine



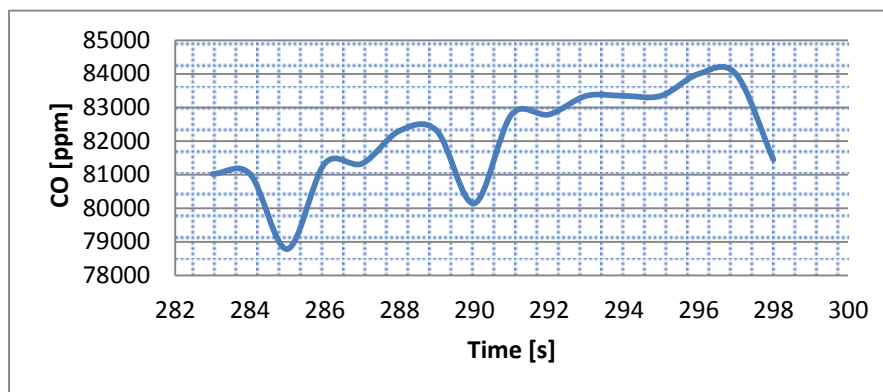


Fig.4 Variation of concentration of concentration of carbon monoxide

The concentration of carbon monoxide and hydrogen cyanide increasing during the firing tests, and these gases are particularly very dangerous for human health.

#### 4. Conclusions

The stand for determining the vertical burning rate was made and determinations were made using electrical cables of 4 and 8 mm diameter for which the vertical burning rate of the test specimens was determined. Smaller cable samples (0.4 mm in diameter) showed a higher average firing rate compared to a larger diameter (0.8 mm diameter). The stand was made for determining the horizontal burning rate and determinations were made for two types of 4mm and 8mm cables. After making the determinations, it can be concluded that the average burning speed for the specimens is inferior to the larger diameter cable.

Toxic products formed in the fire are depending on the chemical reactions and combinations of the resulting products, leading to antagonistic, synergistic effects and other additional interactions. Their nature is directly related to the products involved in the fire and the thermal degradation conditions of the materials and substances. The most significant toxic effluents from common fires are: carbon monoxide (CO), hydrogen cyanide (HCN), carbon dioxide (CO<sub>2</sub>), hydrochloric acid (HCl) and nitrogen dioxide (NO<sub>2</sub>). CO is considered the most dangerous toxic gas because it forms in large quantities at all fires. The test is designed to reproduce real fire conditions and it is essential to make appropriate observations to ensure that conditions are met.

Experimental determinations were made on smoke, nature and concentration of combustion gases by means of instrumental methods existing in the laboratory, respectively determination methods by electrochemical sensors, spectrophotometry, IR sensors, etc. The behaviour of different combustion materials was studied as follows: polymethyl methacrylate, melamine and rubber.

#### Acknowledgements

This paper was developed within the Nucleu-Programe, carried out with the support of MCI, project no. PN 16 4303 07.

#### References

- Abdulrhmann M., *Ways of analysis of fire effluents and assessment of toxic hazards*, Journal of Analytic Sciences, Vol. 5 pp. 1-12, (2015)
- Carloganu C., *Spontaneous combustion in gases and powders*, Technical and Didactical Publishing House, Bucharest, Romania (1986)
- Calamar A.N., Gaman G.A., Pupazan D., Toth L., *Analysis of environmental components by monitoring gas concentration in the environment*, Environmental Engineering and Management Journal Vol 16/issue 6, pp.1249-1256, (2017)
- Gann G., Bryner R., *Combustion products and their effect on life safety*, Fire Protection Handbook, United States of America (2010)
- Strec A.A., Hull T.R., Lebek K., Purser Y.A., Purser D.A., *The effect of temperature and ventilation condition on the toxic product yields from burning polymers*, Fire and Materials, vol. 32, pp. 49-60. (2008)
- Szollosi-Mota A., Prodan M., Nalboc I.V., Suvar S., Radoi F., *Research of combustion parameters and gaseous effluents developed in fire processes*

18<sup>th</sup> International Multidisciplinary Scientific GeoConference Section exploration and Mining- SGEM, pp.753-760 (2018)

Project PN 16430307, Research on the burning behaviour of flammable materials involved in fire/explosion type events, Funded by the Ministry of Research and Innovation in Romania (2017)

SR 652: 2009 Determination of flame-retardant efficiency

SR EN 60695-11-10 Part 11-10: Test flames. Horizontal and vertical flame test methods Horizontal and Vertical Flame Test Methods 50W are based on fixing the test specimen horizontally and vertically, determining the vertical and horizontal firing rates

## Study of methods for assessment of the ignition risk of dust/air explosive atmospheres by electrostatic discharge

Dan Gabor<sup>a\*</sup>, Radu Sorin Mihai<sup>b</sup>, Emilian Ghicioi<sup>a</sup>, Mihaela Părăian<sup>a</sup>,  
Adrian Marius Jurca<sup>a</sup>, Niculina Vătavu<sup>a</sup>, Florin Păun<sup>a</sup>, Cătălin Mihai Popa<sup>a</sup>

<sup>a</sup>National Institute for Research and Development in Mine Safety and Protection to Explosion – INSEMEX, 32-34 G-ral Vasile Milea street, Petroșani, 332047, Romania

<sup>b</sup>University of Petroșani, 20 Universității street, Petroșani, 332006, Romania

---

### Abstract

Because in most cases, fires and explosions cause damage with significant economic and social effects, appropriate measures must be taken to prevent these hazards. These measures aim at preventing explosive atmospheres, followed by preventing the occurrence of ignition sources and then limiting the effects of explosions. One source of ignition of the potentially explosive dust / air atmosphere is static electricity. Static electricity discharges vary greatly as type and degree of initiation. Assessing the occurrence and the possibility of initiating discharges in all kinds of real situations is the most important and most difficult step in analyzing the dangers created by electrostatic charges. Knowing the intensity of the discharge (the amount of energy released) and the sensitivity of the existing explosive atmosphere, as characterized by the minimum ignition energy, it can be determined whether ignition occurs or not. The minimum ignition energy of the flammable dust / air mixture is an essential parameter for assessing the risk of ignition of the potentially explosive dust / air explosive atmosphere by electrostatic discharges. For the most common flammable dusts, it is given in the literature or in databases, but new types of flammable substances are always present, for which this parameter defining the sensitivity of the mixture to ignition by electrostatic discharges must be determined. The methods for determining the minimum ignition energy are multiple, but for a unitary evaluation in the context of the assessment in the field covered by the ATEX Directives (Directive 2014/34 / EU, transposed into GD 245/2016 and Directive 1999/92 / EC, transposed into legislation by GD 1058/2006), they must be standardized at European level. The purpose of this paper is the study of methods for assessment of the ignition risk of dust/air explosive atmospheres by electrostatic discharge.

**Keywords:** dust/air explosive atmospheres, minimum ignition energy, static electricity, electrostatic discharge.

---

### 1. Introduction

In many industrial sectors, flammable substances in the form of dusts are processed, transported or stored. If they are ignited, they can endanger the health and safety of people and can cause material damage. These substances include sugar, coal, wood, grains, certain metals and many organic or synthetic chemicals.

Combustible dusts present fire hazard and may be explosive, mixed with air, in certain concentrations and in the presence of a source of ignition. The existence of this real danger has been confirmed by the events that took place in various economic units, for example: in forage factories, textile industry, steel industry, wood industry, mills, etc.

As regards the occurrence of an explosion, it can only occur if the following conditions are met simultaneously:

- presence of fuel (gases, vapors, dust, combustible mist);
- presence of the oxidant (oxygen, oxidizing substances);
- source of efficient initiation to ensure the activation of the molecules in order to initiate and propagate the rapid combustion reaction.

---

\* Corresponding author. Tel.: +40 254 541 621; fax: +40 254 546 277.  
E-mail address: dan.gabor@insemex.ro.

Since in most cases fires and explosions cause damage with significant economic and social effects, appropriate measures must be taken to prevent such a hazard. These measures aim at preventing the formation of explosive atmospheres, preventing ignition sources and then limiting the effects of explosions. A source of ignition of the potentially explosive dust / air atmosphere may be static electricity.

The critical factor in assessing the electrostatic charge hazards is the probability that a potentially explosive atmosphere and a dangerous electrostatic charge occur at the same time and place. This probability is very high when manipulating a particular product as it can lead to both dangerous loading and the formation of a potentially explosive atmosphere. In particular, this may occur during the handling of bulk non-conductive solids. In particular, this may occur during the handling of bulk non-conductive solids, but even conductive substances can accumulate large dangerous charges if processed in non-conductive equipment. Large electrostatic charges may also occur in non-conductive or non-earthed conductive installations.

## 2. Methods for assessing the risk of initiation of flammable explosive air / dust mixtures by electrostatic discharge.

### 2.1. Formation, accumulation and discharge of electrostatic charges.

Static electricity is one of the most common phenomena in the industry and in the practical activities of everyday life. Accumulation and discharging of electrostatic charges can give rise to hazards and problems in a wide range of industries or work environments. Accumulation and discharging may result in ignition and explosion, especially in the chemical, pharmaceutical, petroleum and food processing industries.

The formation and accumulation of electrostatic charges occurs as a result of charging mechanisms. A charging mechanism that lead to the formation of electrostatic charge is the contact charging. Electrostatic charges are usually generated when any two materials make and then break contact, with one becoming negative and the other positive. Also, another component of the charging mechanism is induction charging, in which case the conductive products may be charged with electrostatic charges from another loaded object in the vicinity. Products can also receive charges by transferring either directly from other objects or through influence through an ion stream.

After separation during the electrostatic charging process, the loads can be recombined very quickly, either directly through contact or through the earth. Charges on a non-conductor are retained due to the strength of the material itself. But in order for a conductor to remain charged, he must be isolated from other conductors and earth.

Under normal conditions, pure gases are non-conductive and charged particles suspended in clouds of dust, mist or spray material can often stay for long periods of time, regardless of conductivity particles themselves.

In all cases, loads leak with a value determined by non-conductor resistances in the system, the process is known as relaxation. The levels of resistance, resistivity, or conductivity that can lead to hazardous situations depend largely on industrial processes.

In many processes there is continuous generation of loads that accumulate on isolated conductors. For example, when a stream of charged liquid or powder flows into an insulated metal container, the potential of the insulated conductor is the result of the balance between the load formation rate and the leakage rate.

The equivalent electric circuit is shown in Figure 1 and the potential of the conductor is given by the equation:

$$V = I \cdot R \left\{ 1 - \exp \left( -\frac{t}{RC} \right) \right\} \quad (1)$$

where:

V is the potential of the conductor in volts;

C is the capacitance in farads;

R is the leakage resistance to earth in ohms;

I is the electrostatic charging current in amperes; t is the time from the commencement of charging in seconds.

The maximum potential is reached when t is high and is therefore:

$$V_{\max} = I \cdot R \quad (2)$$

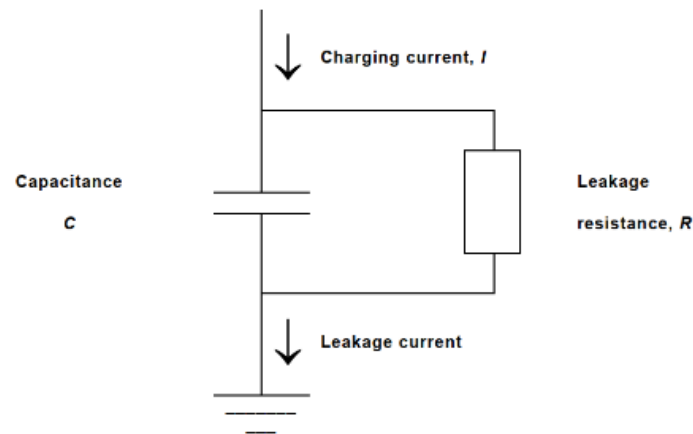


Figure 1 - Equivalent electrical circuit for an electrostatically charged conductor.

The leakage resistance and the capacity of an insulated conductor can usually be measured, by measuring them to determine if dangerous load levels can accumulate. However, this assessment can't be made for suspensions of dust and mist in the air.

Static electricity discharges vary greatly as a type and degree of initiation. The literature relates to the following types of electrostatic discharges:

- Sparks (discharges between two solid or liquid conductors);
- Discharging "Corona" (discharging takes place in sharp areas or at the edges of the conductors, e.g. surfaces with a small radius of curvature). The "Corona" discharge can occur when such a conductor is grounded and moved in the direction of a strong charged object or if the potential of the conductor is greatly increased);
- Brush-type discharges (These discharges can occur when rounded (opposite to the sharp) conductors connected to the grounding network are shifted to load-bearing objects, poorly conductive, for example, between a person's finger and a plastic surface);
- Propagation brush discharges (For this type of discharge it is necessary to have a sheet of high resistivity material and a high dielectric strength with the two surfaces heavily charged with loads but opposite polarity);
- Lightning discharges (In principle, these discharges occur within dust clouds or from dust clouds to earth when the field strength is high due to the charge particles. Such lightning discharges could be observed in the clouds ash during the volcanic eruption);
- Cone discharges (When large silos or containers are filled with a highly charged, weakly dusty dust, a high load density area is generated inside the dust pile).

The incendency of electrostatic discharge varies greatly depending on the type of discharge and environmental sensitivity, characterized by minimal ignition energy.

Assessing the occurrence and the possibility of initiating discharges in all kinds of real situations is the most important and most difficult step in analyzing the dangers created by electrostatic charges. For this reason, table 1 gives the synthesis of the initiation capacity (incendency) of the different types of discharges taking place in practice.

Table 1. Incendency of the different types of discharges.

Type of discharge	Incendency		
	Gases, Vapors		Dust
	MIE < 0.025mJ	MIE > 0.025mJ	
Spark discharge	+	+	+
Corona discharge	+	-	-
Brush discharge	+	+	-
Propagating brush discharge	+	+	+
Cone discharge	+	+	++
Lightning discharges	+	+	+

Thus, an explosion risk assessment must consider the likelihood of electrostatic charges and unloading both equipment and products/material (Figure 2).

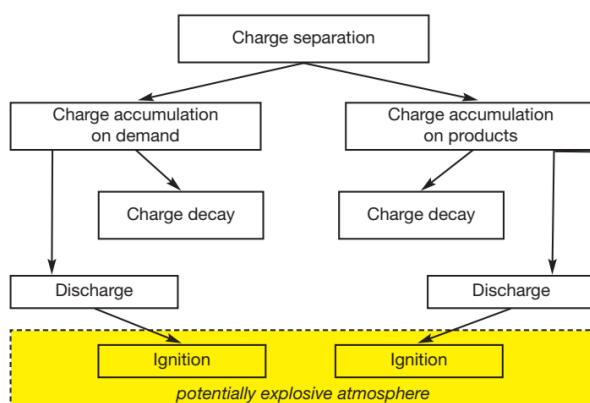


Figure 2 Schematic presentation of the steps leading to the initiation of a potentially explosive atmosphere in the case of electrostatic charges and discharges.

The data required for a reliable analysis are the precise knowledge of the potentially explosive mixture properties that may be present, the resistances or conductivity of the substances, apparatus, packaging, materials and personal equipment used, the volumes and geometric arrangement of the installations and technical devices and the precise knowledge of the conditions existing earthing and potential balancing conditions.

### 1.2 Static electricity for bulk materials.

According to the practical experience, the bulk material ignition capacity with fine particle size and up to granules or chip sizes increases with decreasing particle size and decreasing minimum ignition energy (MIE). The ignition risk assessment must always be based on the minimum ignition energy of the smallest particle that may be present. This class of particles is usually obtained by sifting a sample through a sieve with meshes of 63  $\mu\text{m}$ .

If the relevant minimum ignition energy is greater than 1 J and no flammable gases and vapors are present, special measures to avoid the risk of ignition due to static electricity are usually not required. A possible exception to this is when it is possible to brush propagation discharge.

Bulk materials are classified into three groups according to their resistivity in volume:

- Low resistivity powders with volume resistivity up to 1 M $\Omega$ ;
- Medium-resistivity powders with volume resistivity from 1 M $\Omega$  to 10 G $\Omega\text{m}$ ;
- High resistivity powders with resistivity of 10 G $\Omega\text{m}$  and above.

In practice, dusts with low resistivity are rare. Even metallic powders do not remain conductive for a long time because oxide films are formed on the surface to increase their resistivity. An exception, however, is carbon black.

Bulk material from silos and other containers for bulk materials must be handled and processed in such a way as to avoid the accumulation of dangerous electrostatic charges. Dangerous charges can accumulate on both the bulk material and the walls of the silo or container.

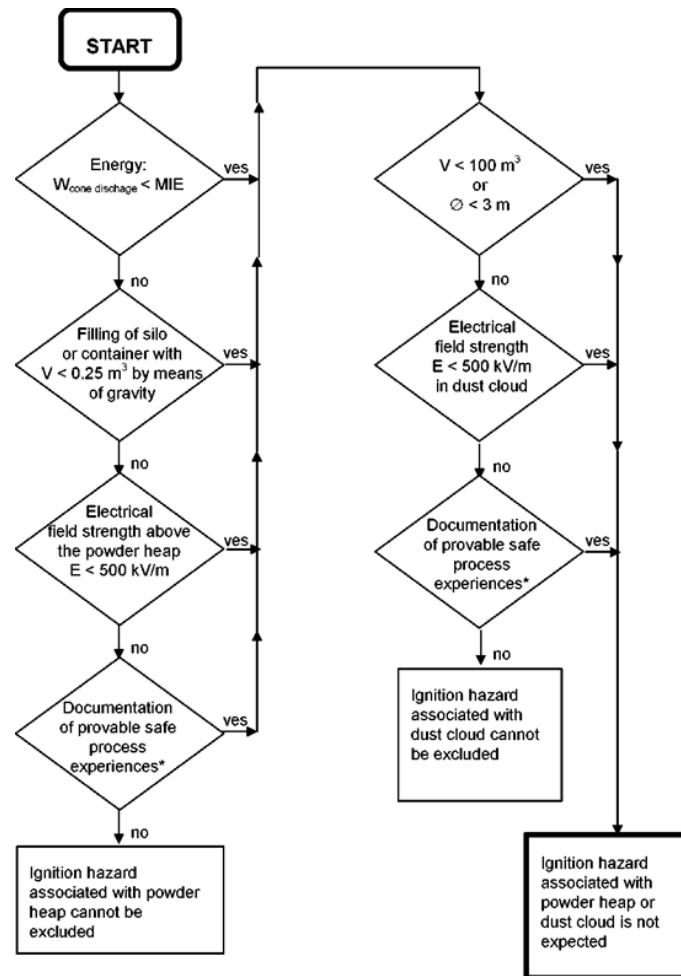
To prevent the risk of explosion, a risk analysis should be made to determine whether the bulk material can be electrostatically charged at a dangerous value during loading into the silo or container. If necessary, measures must be taken to prevent cone discharge, lightning or sparks. The analysis should be based on the resistivity of the bulk material.

For example, for materials with  $\rho > 10 \text{ G}\Omega\text{m}$ , a complete analysis is given in figure 3.

As an alternative to measuring the field strength above the deposit / pile of dust, this field strength should be estimated by modeling the electric field inside the silo taking into account the relaxation of charges during the filling procedure. Such modeling calculations should be based on the mass ratio, bulk density and dust fill rate, permittiveness and relative resistivity of bulk dust, as well as on the silo geometry.

If the radially directed electric field remains below 3 MV/m, the bulk dust field criterion is met. The difference between 0.5 MV/m and the limit of 3 MV/m is based on the distribution of the field inside the silo while the maximum field is always radially directed against the silo wall measured at the silo wall and not axially guided over the storage/pile of dust.

During discharges from silos and containers in the absence of flammable gases and vapors, bulk material is generally not expected to accumulate. Moreover, all downloads and transfer devices need to be analyzed separately. However, it should be borne in mind that most of the unloading operations are a filling operation for the next silo or container. From the analysis presented, it is observed that if the incendivity of the discharge (the amount of released energy) and the sensitivity of the existing explosive atmosphere, as characterized by the minimum ignition energy, is known, it can be clearly established whether the ignition occurs or not.

Figure 3: Assessment of bulk material with  $\rho > 10 \text{ G}\Omega\text{m}$ .

The minimum ignition energy of the flammable dust / air mixture is an essential parameter for assessing the risk of ignition of the potentially explosive dust / air explosive atmosphere by electrostatic discharges. For the most common flammable dusts, it is given in the literature or in databases, but new types of flammable substances are always present, for which this parameter defining the sensitivity of the mixture to ignition by electrostatic discharges must be determined. For information on MIE for dust, see BIA-Report 12/97 "Combustion and explosion characteristics of dusts".

### 3. Minimum Ignition Energy Methods (MIE).

Minimum ignition energy determination methods may be estimation methods or quantitative methods so they are standardized in IEC 61241-2-3, ASTM E2019 and EN 80079-20-2 / EN 13821.

The MIE for dusts varies depending on particular parameters such as particle size distribution, moisture content/solvents and the test method/appliance, respectively. By tests performed in the INCD INSEMEX laboratories with the KSEP test chamber, an estimated ignition envelope can be determined.

Most of the times, however, for the evaluation, a more accurate value of the minimum ignition energy must be known. That is why, in the research program PN PN 18 17 02 01, in Stage II with a final deadline of 2018, a test stand according to the standardized method.

### 4. Conclusions

In order to ensure the safety and health of workers and goods in the industrial sectors processing, storing or transporting substances in the form of flammable dusts, an explosion risk analysis should be carried out to establish protective measures to prevent ignition of potentially explosive atmospheres with different sources of ignition, including static electrification.

The necessary data for a reliable analysis is the exact knowledge of the properties of the potentially explosive mixture that may be present, respectively of its ignition capacity, and the resistances or conductivity of the substances, appliances, packaging, materials and personal equipment used, the volume and geometric arrangement of the



installations and technical devices, as well as precise knowledge of the existing grounding conditions and the conditions of balancing the potential.

According to the practical experience, the bulk material ignition capacity with fine particle size and up to granules or chip sizes increases with decreasing particle size and decreasing minimum ignition energy (MIE). The ignition risk assessment must always be based on the minimum ignition energy of the smallest particle that may be present.

Explosion protection requirements fall within the scope of the European directives ATEX: Directive 2014/34 / EU (HG 245/2016) and Directive 1999/92 / EC (HG 1058/2006). Therefore, minimal ignition energy must be determined by methods / equipment complying with European standards to ensure the repeatability and reproducibility of the test.

In the testing laboratory of INSEMEX at present, only the estimated minimum ignition energy can be determined, with the development of the infrastructure of the testing laboratories with the necessary equipment for the determination of the minimum ignition energy according to the standardized method - within the NUCLEU project PN PN 18 17 02 01 - Researches for developing the assessment and testing of technical equipment designed for use in areas with hazard of explosion and of personal protective equipment.

## **Acknowledgements**

This paper was developed within the Nucleu - Programme, carried out with the support of MCI, project no. PN 18 17 02 01 - Researches for developing the assessment and testing of technical equipment designed for use in areas with hazard of explosion and of personal protective equipment.

## **References**

- Ch. Cesana, R. Siwek, Operating Instructions 20-1-Apparatus 6.0, Kuhner AG;
- Petr Lepik, Dieter Gabel, Wojciech Adamus, Ladislav Mokos, Miroslav Mynarz, Jiri Serafin, Determination Of The Minimum Ignition Energy On Different Devices, Transactions of the VŠB - Technical university of Ostrava,afety Engineering Series Vol. X, No. 1, (2015);
- Dr. Martin Glor, Peter Thumhert, Ignition Hazards Caused by Electrostatic Charges in Industrial Processes, SWISSI, Thuba Ltd. (2015);
- A. Janes - J. Chaîneaux - D. Carson - P.A. Le Lore, MIKE 3 versus HARTMANN apparatus: Comparison of measured minimum ignition energy (MIE);
- SR EN 1127-1: 2011 Atmosfere explozive. Prevenirea și protecția la explozii. Partea 1: Concepte fundamentale și metodologie;
- SR EN 60079-0:2013/A11:2014 Atmosfere explozive. Partea 0: Echipamente. Cerințe generale;
- SR EN ISO 80079-36:2016 Atmosfere explozive Partea 36: Echipamente neelectrice pentru atmosfere potențial explozive. Metodă și cerințe de bază (SR EN 13463-1:2009 Echipamente neelectrice pentru atmosfere potențial explozive. Partea 1: Metodă și cerințe de bază);
- IEC 60079-32-1 TS: Explosive atmospheres – Part 32-1: Electrostatic hazards. Guidance;
- Directiva 2014/34/UE, transpusă în HG 245 / 2016 privind stabilirea condițiilor pentru punerea la dispoziție pe piață a echipamentelor și sistemelor de protecție destinate utilizării în atmosfere potențial explozive;
- Directiva 1999/92/CE, transpusă în legislația noastră prin HG 1058/2006, privind cerințele minime pentru securitatea și protecția sănătății lucrătorilor aflați în potențial pericol în atmosfere explozive.

# Identification of burning accelerators in investigation of fires using the Infrared Spectroscopy Method (FTIR)

Niculina Sonia Șuvar\*, Emilian Ghiciei, Irina Nălboc, Andrei Szollosi-Moța, Maria Prodan

*National Institute for Research and Development in Mine Safety and Protection to Explosion INSEMEX Petroșani, 32-34 Gen. V. Milea Str., Petroșani, 332047, Romania*

---

## Abstract

The combustion potentiality of a substance or explosive mixture can be identified by ascertaining the structure of their chemical compounds using several methods, including infrared spectroscopy (FTIR).

The objective of this paper is to identify certain hazardous substances that have generated explosion or fire type events, by using modern techniques that consist in physical-chemical characterization of substances or their compounds.

Infrared absorption spectra were assessed by using the attenuated total reflection analysis technique (ATR) and their evaluation was performed by using libraries within the device's software.

The use of this technique is safe, being a convenient method in terms of sample preparation and quantity of sample used, the main advantage being the certainty of results.

Keywords: ATR analysis, combustion, explosive mixture, hazardous substance, infrared spectroscopy

---

## 1. Introduction

Fourier Transform Infrared Spectrometry has become one of the main techniques used when analyzing samples of particular specificity that require a non-destructive analysis. (Radu et al., 2012).

In this study some experimental results are presented, which, through the arguments brought, justify the importance of using this technique in elucidating aspects of the structural characteristics of certain types of evidence.

The research was carried out on samples taken from material evidences, used and experimented in the elaboration of reports for technical expertise of explosion or fire type events.

The results of the spectrograms allow the identification of certain types of substances, specific to the event location. In the case of identification of the IR spectrum waveform numbers, specific for burning accelerators (e.g.: gasoline, diesel, oil, etc.), the team of researchers involved in the elaboration of the technical expertise report for the investigated event could correlate the FTIR data obtained with all other relevant elements, in order to determine the causes that led to the occurrence of the event (Ghiciei et al., 2018).

## 2. Determination method

Fourier Transform Infrared Spectrometry (FT-IR) is a non-destructive technique that involves low analytical costs and fast responses. These features make FT-IR spectrometry one of the most widely used analysis techniques in physico-chemical analysis laboratories. The advantages of this technique have brought to specialists' attention and the problem addressed is very broad: the characterization of some substances in order to identify certain combustion accelerators. (Merticaru and Petroviciu, 2005).

Spectrometry is used both as a qualitative method for identifying the presence of a substance in a solution, as well as a quantitative method for identifying the concentration of a substance in a solution. The method can also be used to determine the equilibrium constant of a solution (Berthomieu and Hienerwadel, 2009).

---

\* Corresponding author. Tel.: +40 254 541621; fax: +40 254 546277.  
E-mail address: sonia.suvar@insemex.ro.

The IR range of the electromagnetic wave spectrum contains radiation with wavelengths ranging from  $0.8 \mu\text{m} \leq \lambda \leq 1000 \mu\text{m}$ . This range can be divided into three sub-domains: near-infrared ( $0.8 \mu\text{m} \leq \lambda \leq 2.5 \mu\text{m}$ ), mid and long wavelength infrared (between  $2.5 \mu\text{m} \leq \lambda \leq 25 \mu\text{m}$ ) and far infrared (over  $\lambda = 25 \mu\text{m}$ ).

In most laboratories, Fourier Transform Infrared Molecular Absorption Spectrometry and Fourier Transform Raman Spectrometry are used as complementary techniques, since each of them exhibits certain aspects for a given sample (Varma et al., 1989; Birzescu et al., 2009).

### 3. Apparatus

For the identification of combustion accelerators, the samples taken at the event site were analyzed by infrared spectrometry method with a FT-IR type equipment, Nicolet IS 50, made by ThermoScientific, with integrated ATR module with diamond crystal, with the range of  $4000 - 400 \text{ cm}^{-1}$  (Figure 1).

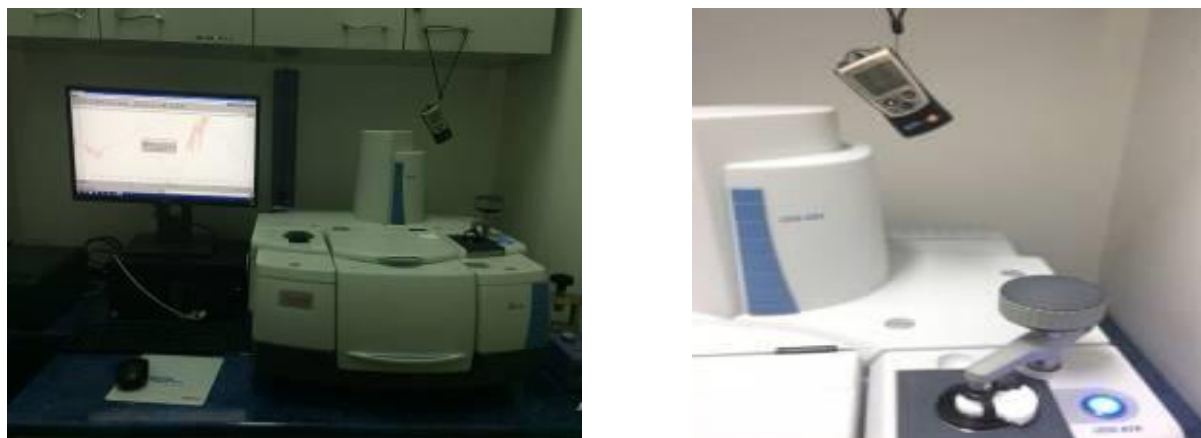


Fig. 1. (a) Nicolet IS50 Infrared Spectrometer equipment; (b) ATR module with diamond crystal and device for analyze of volatile substances.

Infrared absorption spectra were recorded at a resolution of  $4 \text{ cm}^{-1}$ , using ATR (attenuation of total reflection) analysis technique, as follows:

- Attenuation of total reflection, performed directly on the combustion residue samples - non-destructive analysis;
- Attenuation of total reflection, performed on n-hexane extract, with background read on solvent.

In order to identify the contaminants or compounds found in very low concentrations, the sample was subjected to an extraction operation using solvent (n-hexane), at room temperature.

The experimental data obtained was evaluated using the OMNIC software (Thermo Nicolet Corporation), as well as the dedicated libraries containing more than 40000 IR spectrograms (ThermoScientific, 2013).

### 4. Results and Discussions

For the identification of certain combustion accelerators in fire events, two cases were analyzed:

- A case where no combustion accelerators have been identified;
- A case where combustion accelerators have been identified.

For each sample, a spectral analysis was performed directly on the residue, as well as an analysis of the n-hexane extract from the residue.

a) For the first case, 2 samples were taken from the site where the fire event took place and being analyzed in the Laboratory for Physico-Chemical Analysis, the samples representing the residues of textile materials and carbonized residues (Fig. 2).



Fig. 2. Scraps of textile materials – 1<sup>st</sup> case.

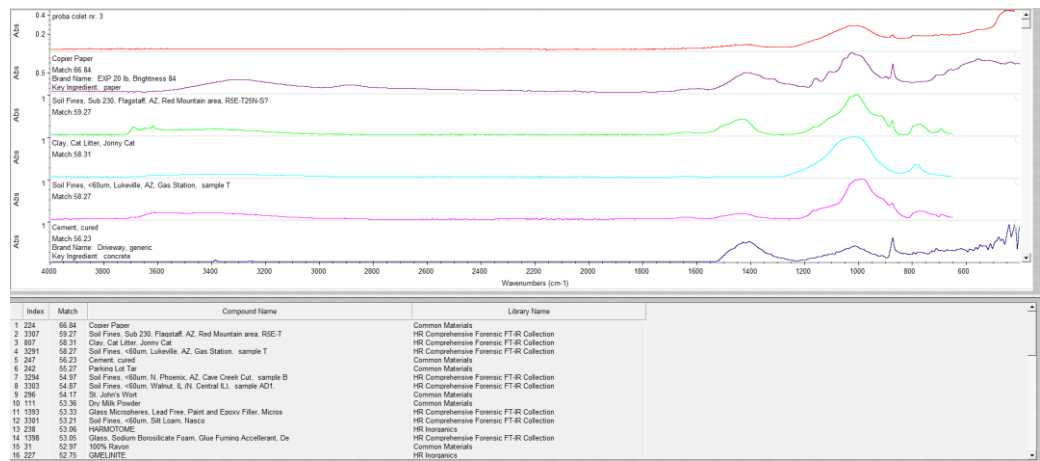


Fig. 3. IR spectrum of the textile material sample, untreated with n-hexane

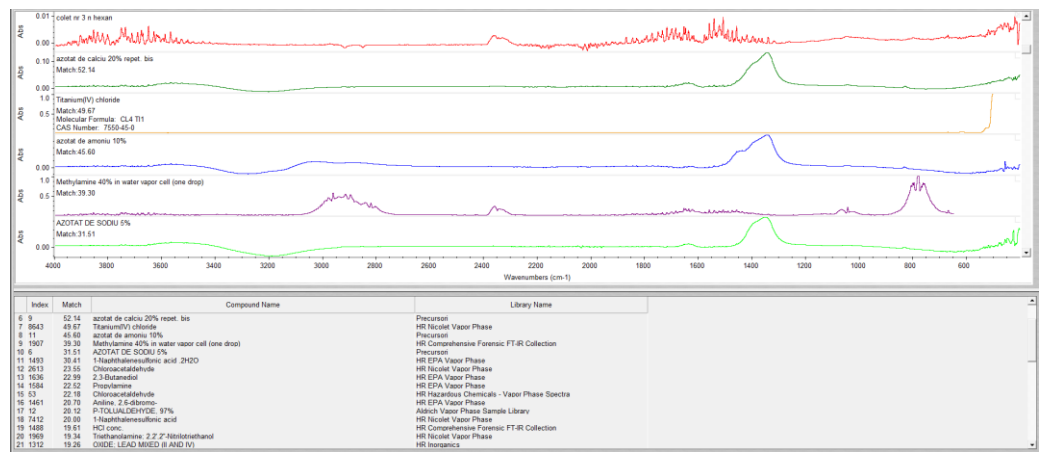


Fig. 4. IR spectrum of the textile material sample, treated with n-hexane

Figure 5 presents a sample consisting in carbonized residues, other than textiles.



Fig. 5. Sample consisting in carbonized residues, other than textile materials.

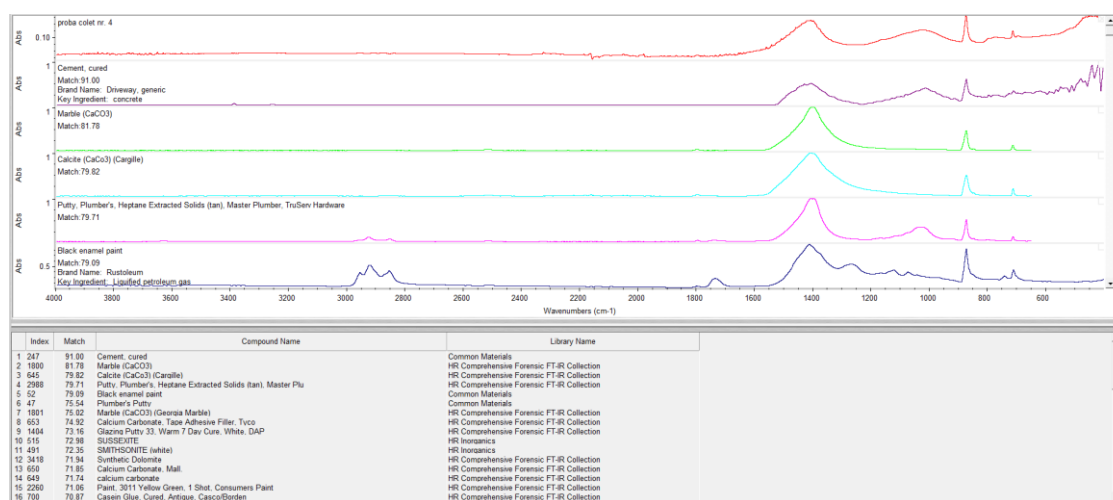


Fig. 6. IR spectrum of carbonized residues, other than textile materials, untreated with n-hexane

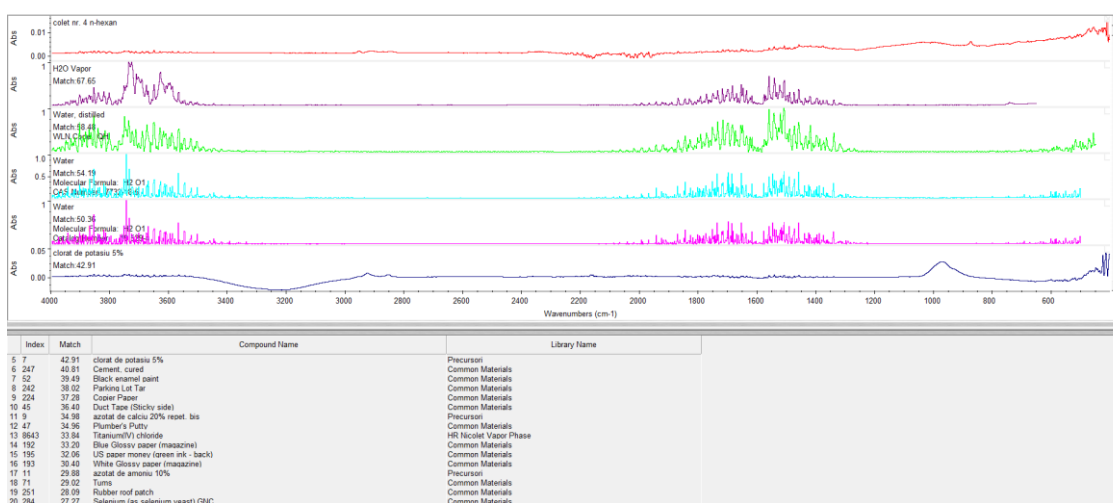


Fig. 7. IR spectrum of carbonized residues, other than textile materials, treated with n-hexane

In the two analyzed samples, no elements were identified that would lead to the existence of specific firing accelerators specific to the Arson type effects.

b) For the second case, 3 samples that were taken from the event site were analyzed in the Physical-Chemical Analysis Laboratory. The samples contained combustion residues (Fig. 8).

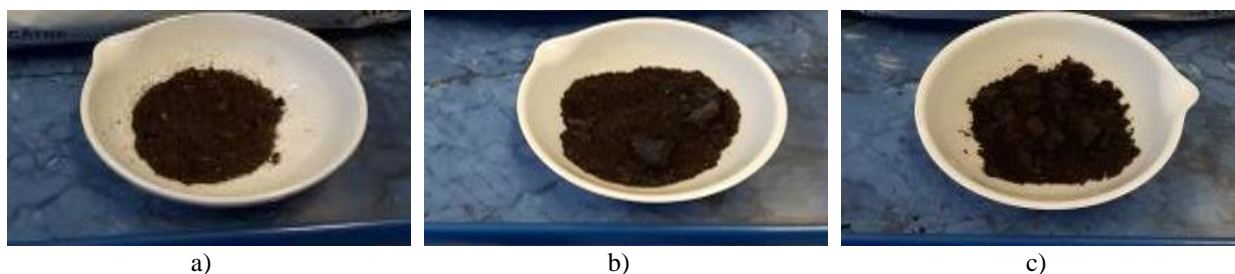


Fig. 8. The three samples consisting in combustion residues.

For exemplification purpose, Figures 9 and 10 show the IR spectra of sample c), both before and after the treatment with n-hexane.

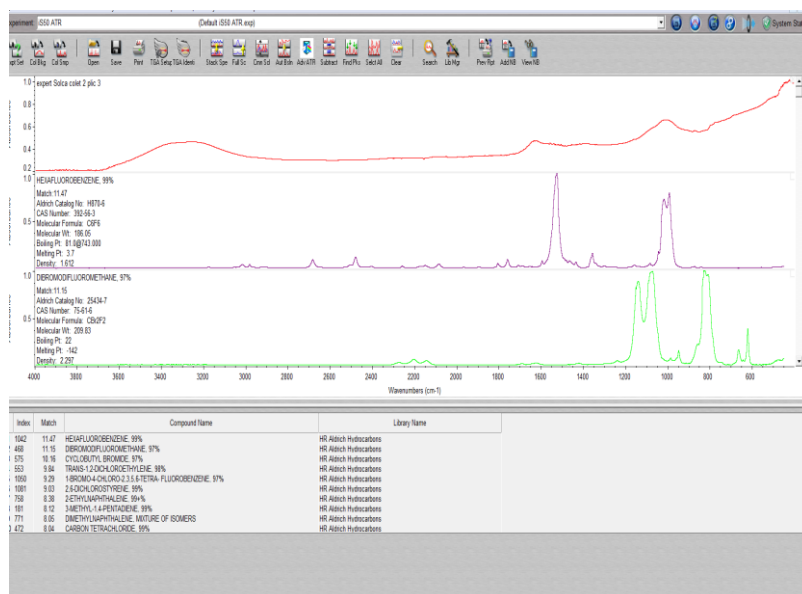


Fig. 9. IR spectrum for sample c), untreated with n-hexane.

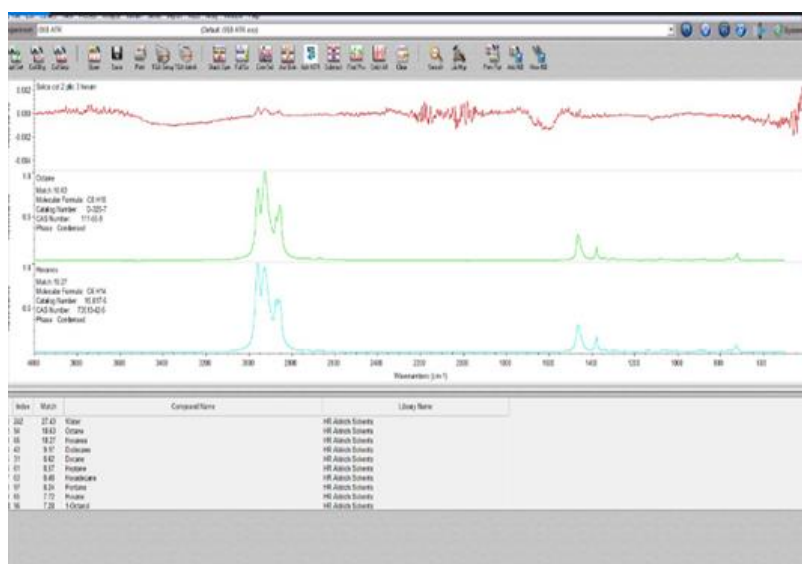


Fig. 10. IR spectrum for sample c), treated with n-hexane.

In this case, following the analysis carried out on the three samples, the ATR-FTIR analysis of n-hexane extract, there have been identified aliphatic hydrocarbons from the series of higher alkanols and aromatic hydrocarbons such as: pentane, hexane, heptane, octane, dodecane, cyclohexane, benzene, xylene, all these substances also being found in the chemical composition of petroleum products.

## 5. Conclusions

The ATR-FTIR spectral analysis method has proven to be an effective method for identifying the waveforms numbers specific to certain combustion accelerators and is particularly useful in investigating fire / explosion type events. The paper presents, in the second case under consideration, specific elements of petroleum products, which, together with other relevant data of the event, allow the confirmation of the Arson effect.

## 6. Acknowledgements

This paper was developed within the Nucleu Programme, carried out with the support of Romania Ministry of Research and Innovation - MCI, project no. PN 18.17 01 01, Development of the institutional capacity for technical expertise of the explosion / fire type events (in Romanian).

## References

- Berthomieu, C., Hienerwadel, R., *Fourier transform infrared (FTIR) spectroscopy*, Photosynthesis Research, September 2009, Vol. 101, Issue 2–3, pp. 157–170, (2009)
- Birzescu, M., Niculescu, M., Dumitru, R., Carp, O. and Segal, E., *Synthesis, structural characterization and thermal analysis of the cobalt(II) oxalate obtained through the reaction of 1,2-ethanediol with  $\text{CO}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$* , J. Therm Anal Calorim, 96, pp. 979-986, (2009)
- Ghicioi, E., Găman, G.A. et al., *Development of the institutional capacity for technical expertise of the explosion / fire type events (in Romanian)*, Nucleu Programme PN 18.1701 01, (2018).
- Merticaru, C., Petroviciu, I., *Utilizarea tehnicii FT-IR în conservarea și restaurarea obiectelor de patrimoniu*, Revista Muzeelor, pp. 96-100, (2005)
- Radu, G.L., Truică, G.I., Penu, R., Moroeanu, V., Litescu, S.C., *Use of the Fourier Transform Infrared Spectroscopy in Characterization of Specific Samples*, U.P.B. Sci. Bull., Series B, Vol. 74, Issue 4, (2012)
- ThermoScientific, *Nicolet iS50 Spectrometer User Guide*, Thermo Fisher Scientific, Revision C, (2013)
- Varma, H.K., Kumar, K.P., Warriar G.K. and Damodaran, A.D., *Thermal decomposition of citrate precursor for 1-2-3 high-Tc superconductor*, Journal of Materials Letters, 8, pp. 1313-1316, (1989).



## Elements of disaster management and first aid

Lorand Toth\*, George Artur Găman, Angelica-Nicoleta Călămar, Daniel Pupăzan, Cristian Nicolescu, Izabella Kovacs

*<sup>1</sup>National Institute for Research and Development in Mine Safety and Protection to Explosion – INSEMEX Petroșani, 32-34 G-ral Vasile Milea Street, Postcode: 332047, Petroșani, Hunedoara County, Romania*

---

### Abstract

Disasters represent a permanent threat to sustainable development and annually generate many human casualties and material losses; at the same time, the beginning of this millennium is characterized by an ever-increasing impact of human activities on Earth.

It is also worth mentioning a paradox of contemporary society's attitude towards disasters: allocation of material and human resources to prevent and mitigate the effects of disasters has greatly increased, but at the same time the development of human society is a factor contributing to disasters and / or amplifying their consequences.

People's health can be unexpectedly threatened both by natural disasters, whether in traffic, during leisure time or at work in different ways, either as a result of a traumatic event such as an accident at work. A quick intervention in the event of an accident can save a person's life or prevent aggravation of injuries suffered.

Health, physical integrity or even the life of victims depend on how first aid is given. Everyone needs to know how to proceed to save someone's life or how to reduce the negative consequences upon injured persons.

*Keywords:* disasters; first aid; vital functions; resuscitation.

---

### 1. Introduction

A hazard is considered a disaster if there are at least ten deaths or 50 injured people and material losses of more than one million dollars (Alexander, 1993). They can be classified according to several criteria: way of development (genesis), event duration, affected area, number of victims, complexity of phenomena etc. ([www.meteoalarm.eu](http://www.meteoalarm.eu)).

1) Depending on genesis, hazards can be differentiated into:

a. Natural hazards, which in turn comprise two large groups of phenomena generated by endogenous and exogenous agents.

Endogenous hazards include volcanic eruptions and earthquakes, phenomena that by their amplitude often generate loss of life and material damage, in many cases.

Exogenous hazards part in: climate hazards (tornadoes, thunderstorms, lightning, hail, glaze frost, drought, etc.), geomorphological hazards (erosion, landslides) (Toth, 2018), hydrological hazards (floods), oceanographic hazards (ocean level rise), biological hazards (epidemics, invasions of insects and rodents), biophysical hazards (fire), astrophysical hazards (meteorites).

b. Anthropogenic hazards are generated by different human activities and include accidents in industry, agriculture and transport (Hogan et al., 1999). Technological disasters, especially those related to chemical and radioactive materials, have a bigger echo, leading to change of legislation in the field or initiation of new regulations.

2) Depending on the affected area, hazards are:

- Global, systemic hazards, such as climate warming tendency caused by artificial greenhouse effect, ozone depletion, the rising tendency of ocean level;

- Global hazards with regional effects such as desertification and soil erosion. These become global by cumulation (Toth, 2018);

- Regional hazards that affect large areas across continents and oceans and include storms, water, air and soil pollution;

---

\* Corresponding author. Tel.: 0723684391; fax: 0254 546 277.  
E-mail address: [lorand.toth@insemex.ro](mailto:lorand.toth@insemex.ro)



- Local and punctual hazards such as landslides, volcanic eruptions, earthquakes.

3) Depending on size of the effects (number of affected persons, material damage, environmental damage), the hazards are differentiated into (Toth, 2018):

- Low-impact hazards that cause small damage that can be remedied by local forces;
- Hazard with severe effects, causing disruptions in the functioning of society, major damage and injuries that require the intervention of civil protection organizations and other competent bodies;
- Disasters (catastrophes) that cause serious disruption or disturbances in the functioning of society and generate human casualties, material damage and environmental damage (Okumura et al., 1996). These effects outweigh the ability of society to respond effectively through the use of local resources, requiring intervention and aid at national and international level.

## **2. National / international approach to disaster prevention**

The reform of public administration is part of the Romanian Government's action to promote a modern society, compatible with European standards. The reform implies enacting, implementation and assimilation of the administrative values set defining the European space, by the Romanian public administration system: transparency, predictability, accountability, adaptability and efficiency.

Evolution of society imposed, as a necessity "sine qua non", the enacting of legislative initiatives that would provide the legal basis for civil emergency management, with particular attention to disasters. Furthermore, Romania's option regarding NATO and EU integration has provided a bridge between bodies with responsibilities in the field – NATO's High-Level Emergency Planning Committee, as well as structures of European Union.

In Romania, the management of various types of crisis by domains (mobilization, war, emergency, siege, disaster, civil protection, etc.) is regulated by specific laws and their management is ensured through permanent or temporary structures on each domain.

In 2004, the Romanian Government adopted the legislative framework (GEO 21/2004 with subsequent amendments and completions) for the establishment of the National System for Emergency Situation Management for the provision of resources and actions coordination in emergency situations, in the conditions in which Romania presents great vulnerabilities to natural and anthropic disasters, such as (Toth, 2018):

- earthquakes - Bucharest is the European capital with the highest seismic risk and one of the 10 most exposed cities in the world;
- floods - annual events with great material and human damage;
- landslides - about 20% of the territory has favourable conditions;
- ecological accidents at and not only mining sites.

The normative act regulates the establishment of structures with attributions in the field of emergency management, at central and territorial level, namely coordination, planning and decision support, with temporary or permanent activity, placed in a hierarchical system according to administrative-territorial and domain of responsibility criteria. These structures ensure the unitary and permanent management of all activities regarding planning and implementation of measures to prevent, limit and remove the destructive effects of emergency situations.

The National Emergency Management System is organized by the public administration authorities and consists of a network of bodies, agencies and structures empowered to handle emergency situations, established by levels or areas of competence and has the necessary infrastructure and resources for fulfilling its duties.

Basically, the national system regards:

- committees for emergency situations;
- General Inspectorate for Emergency Situations;
- professional community public services for emergencies;
- operational centres for emergency situations;
- commander of action.

Internationally, there are several agreements and strategies for disaster prevention, including:

- The United Nations (UN), by Resolution 236 of 1989, decided to organize a comprehensive research program titled "The International Decade Natural Disasters Reduction" (IDNDR).

- The "Towards Partnerships for Disaster Reduction in the 21<sup>st</sup> Century" International Forum, which was held in Geneva in July 1999, essentially delivered a political message emphasizing the need to integrate risk management and disaster reduction in government policies of each state. The political process in Geneva included the enactment of two documents, namely: "A Safer World in The Twenty-Century: Risk and Disaster Reduction" (Burgess, et al., 1997) and the "A Geneva Mandate on Disaster Reduction", which highlighted the consensus among participants in all sectors involved - governments, international organizations, non-governmental organizations, private sector - on the need to continue global integrated research on disasters.

The International Strategy for Disaster Reduction was developed in 2000, focusing on increasing population involvement, linking with sustainable development, developing partnerships and networks. The objective of the International Disaster Reduction Strategy is to educate the public to increase collaboration with public authorities to build structures that are resistant to potential disasters that threaten them.

In 2002, the Johannesburg Implementation Plan (World Summit on Sustainable Development) included a new section - "An integrated, multi-hazard concept on vulnerability, risk assessment and disaster management."

The complex risk management strategy adopted in Istanbul in 2004 mentions systemic integration (risk assessment, emergency preparedness, disaster prevention and disaster risk financing) as well as reducing the exposure of states to economic losses.

In 2005, in Hyogo, Japan, the Hyogo Framework for Action 2005-2015 was adopted to build resistance of nations and communities to disasters.

Other global programs, which meet efforts of thousands of specialists trying to find solutions to serious problems and uncertainties surrounding environmental changes, are: The International Geosphere-Biosphere Program, the International Program the Human Dimension of Environment Global Changes, the Strategic Disaster Reduction Initiative, Climatic World Program etc.

### **3. Disaster risk management**

The objective of risk management is to bring together all the elements and actors in the disaster management system, to develop disaster mitigation tools based on prevention and intervention strategies, transfer and mutual exchange of knowledge, education and decision-making techniques.

Disaster management considers the disaster manifestation stages and includes the following elements: assessment and evaluation of risks and vulnerabilities; response to disaster; appraisal of disaster; rehabilitation and reconstruction.

The assessment and evaluation of risks and vulnerabilities makes an estimate of the magnitude of each potential risk and importance of this risk for population and the environment (Băbuț, et al., 2011).

Disaster risk assessment is very important, as the hazards interact at different spatial and temporal levels, developing locally, regionally and internationally. Besides the individual study of potential hazards, it is important to have a multidisciplinary understanding and an integrated analysis of the different processes, given the fact that disasters are often complex.

Vulnerability assessment is a key component of risk management; qualitative and quantitative assessment of vulnerability of objects and systems exposed to risk of disaster is required.

The factors contributing to increased disaster vulnerability are:

- fundamental causes - poverty, limited access to resources, cultural model of population;
- lack of education, skills, local investment, low capacity of intervention of public institutions;
- degree of urbanization, environmental degradation, population growth, state of transition of cultural models;
- unsafe conditions / fragile environment - dangerous locations, buildings and high-risk infrastructure;
- fragile local economy – low standard of living / lack of information and public awareness.

Response to disaster is all actions taken by authorities and population in the face of disaster. It includes warning, security, communication and information management actions, logistics and supplies, post-disaster assessment, research and rescue of survivors, post-disaster assistance (assistance to the population, maximizing the number of survivors, restoring essential services, restoring damages) and emergency management operations.

Assessment disaster entails determining the impact of disaster on society and is an interdisciplinary process, its priorities being establishing the need for immediate emergency actions, to save and sustain the life of disaster survivors and identify opportunities to speed up the restoration of infrastructure, services and development. This is done considering various phases of disaster manifestation, namely:

Warning phase (actuating the population group for whom life-saving measures are taken and facilities to mitigate the impact of a potential disaster and activating arrangements in the preparedness plan from the perspective of appreciation);

Emergency phase (confirming the urgency reported and damage estimation, identification, characterization and quantification of population at risk of disaster, help to define priorities for action and resources needed to reduce immediate risks, identifying local capacity to respond, including organizational resources, medical and logistical support, help to anticipate serious future problems and support for immediate response management and control);

Rehabilitation phase (identifying the priorities of affected population, identifying government policies for post-disaster assistance, estimating additional support from national and international sources for mitigation, recovery and monitoring of these measures results);

Restoration phase (assessment of the destruction of significant economic resources and their implications for development policy, assessing the impact of disaster in current development programs and identifying new development opportunities created by disaster).

Rehabilitation and reconstruction comprise the longest period of the post-emergence recovery phase. Rehabilitation takes place in the immediate aftermath of disaster and is the transition between mitigation and reconstruction. The reconstruction period requires full restoration of services and infrastructure, building construction, restoration of destroyed infrastructure and, last but not least, economic revitalization.

#### 4. Examination of the victim and cardio-pulmonary resuscitation

Before any procedure regarding the victim's examination, it is essential to ensure the safety of the rescuer, as well as the team's and not lastly the victim's. Once the safety conditions have been ensured, the rescuer must begin evaluating the victim's condition so that he can assist in the order of priority and severity of the present injuries. The rescuer must conduct a quick and thorough survey to assess changes in vital functions, endangering the life of the victim.

**Primary examination** aims to detect the presence of situations that can endanger the victim's life as well as to provide adequate emergency assistance (Chiorean et al., 2002).

In the victim's main survey, the rescuer must keep track of the following list of priorities:

1. Assessing the state of awareness;
2. Assessing the breathing;
3. Assessing blood circulation;

*Assessing the state of awareness* - a victim is aware if he/she reacts when stimulated. To do this, gently shake the victim's shoulders and ask out loud: "Can you hear me?" "Are you okay?" If the victim is unconscious, you must immediately call for more help. If he/she doesn't respond, the victim is unconscious and in potential danger of death.

*Breathing assessment* - first stage of respiratory evaluation is the release of the respiratory tract. Obstruction of airways is a very serious situation that can occur in unconscious victims by relaxing the muscles, by accumulation of secretions (vomit, blood, etc.) or by the presence of foreign objects such as teeth, prostheses, food, earth, leaves, etc.

After releasing the airways, approach the victim's face, examine the thorax while maintaining the airways open (Prentice and Charles, 2002). Check the breath for 10 seconds using the following three steps:

Look - if there is a vertical movement of the chest;

Listen - the flow of air that passes into the victim's airway;

Feel - the air expired by the victim.

*Blood circulation assessment* - arterial pulse is a peripheral manifestation of the heart's mechanical activity, consisting of a periodic expansive wave, synchronous with ventricular ejection, perceived upon palpation of an artery on the underlying tissue. In a victim with impaired circulation, it is possible to feel the pulse in large arteries, especially in carotid, femoral, radial or humeral. To find the pulse in the carotid artery, place two fingers (index and middle fingers) on the larynx (Adam's apple) and gently slide towards the outside of the neck to find a channel between the trachea and the sternocleidomastoid muscle. Gently palpate, without compressing, for 10 seconds.

**Cardiovascular resuscitation** is an important technique performed when the victim does not breathe and / or the heart stops beating (Azoulay and Sprung, 2004). Stopped breathing without a stopped heart allows intervention within 3 to 12 minutes, to have a chance to succeed in saving the victim's life (Saner et al., 2002).

Cardiovascular resuscitation implies (Beauchamp and Childress, 2008):

A) Opening and cleaning the nasal cavity/mouth and ensuring the airways are released by: tilting the head backwards and lifting the chest.

B) Resumption of blood circulation by external cardiac massage.

C) Resumption of artificial breathing movements by mouth-to-mouth breathing or mouth-to-nose breathing.

**Artificial breathing.** It is performed in both respiratory and cardiac arrest. The resuscitation manoeuvres begin with the release of upper respiratory tract (mouth, nose, oropharynx) (Bossart et al., 1998). Release of the upper respiratory tract is sometimes sufficient for the victim to resume breathing without the need for artificial respiration (Babbs, 2002).

The victim will be positioned in dorsal decubitus, the rescuer sits on his knees at the victim's head on the side and performs, in the following order, (fig. 1): 1. Head hyperextension; 2. Release of the upper respiratory tract; 3. Disjoint of mandible; 4. Nose pins - nose closure prevents the air powerfully inserted by the rescuer into the victim's mouth coming out through the nostrils, it being forced to fully enter the lungs. This manoeuvre can be performed with special pins from the aid kit or by hand.

After this preparation, the rescuer draws air in the chest (deep inspiration), followed by a willing apnea, then quickly applies, with wide mouth open, his lips over the victim's open mouth, which was previously covered with a piece of gauze or clean handkerchief and powerfully breaths the air from his lungs into the victim's airway (Ciontu, et al., 2006). Then the rescuer rises, performs a new inspiration, while letting the patient's nostrils and mouth open, so the air comes out of the lungs, and breaths air into the lungs again, repeating this sequence for 14-16 times / min. For varied reasons (the mouth of the victim cannot be opened, the presence of injuries to the victim's mouth, jaw fractures, the mouth of the rescuer is smaller than that of the victim), the mouth-to-mouth breathing is aborted and the breathing "mouth to nose" is initiated. This method generally retains the same working times described in the previous method.



Fig. 1. (a) “mouth-to-mouth breathing”, (b) “mouth-to-nose breathing” artificial breathing

**External cardiac massage.** Resuscitation of a subject in cardiac arrest (fig. 2) is mandatory to be performed in parallel with artificial breathing, as cardiac arrest is invariably followed, in 20-30 sec., by respiratory arrest (Flabouris and Bridgewater, 1996). The victim will be placed in in dorsal decubitus position on a rough surface.

The rescuer sits on the side of the victim and transversely applies the left-hand bridge to the lower 1/3 of the stern and the other hand crosses the first. With two hands crossed and thumbs elevated to avoid compressing the ribs (which can fracture), rescuer’s shoulder line above the victim sternum, elbows in extension, helped by its own weight, the rescuer performs rhythmic pressures on the sternum (DeLorenzo, 1997). Each compression will be sharp and short (approx. 1 sec.) and will exert a vertical pressure of the sternum toward the spine so that the sternum is sunken by about 5-6 cm (Haukoos, et al., 2004). After each compression, the sternum is allowed to return to its original position without raising the hands of the sternum.



Fig. 2 External cardiac massage

Breathing may be delayed after the heart resumes its activity after external cardiac massage, so artificial respiration continues until the patient can breathe normally (Herlitz, et al., 2006). Even if the patient resumes respiratory and cardiac activity, it is forbidden to lift him from the horizontal position because at any time the cardio-respiratory arrest can reappear.

Resuscitation continues until:

- qualified help arrives and takes over resuscitation; or
- the victim gives signs of life: he moves, opens his eyes or breathes normally; or
- the rescuer is physically exhausted.

## 5. Conclusions

Disasters (catastrophes) cause serious disruption or disturbances in the functioning of society and generate human casualties, material damage and environmental damage. Evolution of society imposed the enacting of legislative initiatives that would provide the legal basis for civil emergency management, with particular attention to disasters.

Risk management requires systemic integration (risk assessment, emergency preparedness, disaster prevention and disaster risk financing) as well as reducing exposure of states to economic losses.

Prior to any first aid procedure, it is essential to ensure the safety of rescuers, as well as the team’s and, last but not least, the victim’s. Awareness is needed so that everyone knows how to perform first aid to save someone’s life, or to reduce the negative consequences for an injured person.

## Acknowledgements

This paper was developed within the Nucleu-Programme, carried out with the support of MCI, project no. PN 18 17 02 02 (Research on improving health and safety in hazardous environments with explosive, flammable and toxic atmospheres)

## References

- Alexander, D. E., *Natural Disasters*, UCL Press, London, (1993);  
 Azoulay E., Sprung CL., *Family-physician interactions in the intensive care unit*, Crit Care Med, (2004)

- Babbs C.F., *Circulatory adjunct: Newer methods of cardiopulmonary resuscitation*, Cardiol Clin, (2002);
- Băbuț, G.B., Moraru, R.I., Cioca, L.I., „Kinney methods”: useful or harmful tools in risk assessment and management process? Proceedings of the 5th International Conference on Manufacturing Science and Educations (MSE 2011), Volume II, pp. 315-318, Sibiu, Romania, 02-05.06. (2011)
- Beauchamp T.L., Childress, J., *Principles of Biomedical Ethics*, 6<sup>th</sup> ed. Oxford University Press, (2008);
- Bossaert L., Van Hoeyweghen R., Cerebral Resuscitation Study Group: Evaluation of cardiopulmonary resuscitation (CPR) techniques, Resuscitation, (1989);
- Burgess J.L., Keifer M.C., Barnhart S., et. al., *Hazardous materials exposure information service: Development, analysis, and medical implications*, Ann Emerg Med, (1997).
- Chiorean M., Copotioiu S., Azamfirei L., Management of critical patients, Technical-Managerial Support, Vol I, University Press Publishing House, Targu Mures, ISBN 973-7788-02-8, (2002);
- Ciontu Călin, Dimitriu Ioana, Georgescu Valentin, et al., *Cardiopulmonary and cerebral resuscitation in adults - Course notes* - Alpha MDN Publishing House, ISBN (13) 978-973-7871-60-2, Buzău, (2006).
- DeLorenzo R.A., *Mass gathering medicine*, Prehospital Disaster Med, (1997)
- Flabouris A., Bridgewater F., *An analysis of demand for first-aid care at a major public event*, Prehospital Disaster Med, (1996).
- Haukoos JS., Lewis RJ., Niemann JT., *Prediction rules for estimating neurologic outcome following out-of-hospital cardiac arrest*, Resuscitation, (2004)
- Herlitz J., Svensson L., Silfverstolpe J., et. al., *Characteristics and outcome amongst young adults suffering from out-of-hospital cardiac arrest in whom cardiopulmonary resuscitation is attempted*, Journal of Internal Medicine, (2006)
- Hogan D.E., Lillibridge S.R., Waeckerle J., et. al., *Emergency department impact of the Oklahoma City terrorist bombing*, Ann Emerg Med, (1999)
- Okumura T., Takasu N., Ishimatsu S., et al., *Report on 640 victims of the Tokyo subway sarin attack*, Ann Emerg Med, (1996).
- Prentice H., Charles E., *Advanced Airway Management*, MD, FACEP, ISBN 0-13-088191-0, (2002).
- Saner H., Borner Rodriguez E., Kummer-Bangerter A., Schuppel R., *Quality of life in long-term survivors of out-of-hospital cardiac arrest*, Resuscitation, (2002).
- Toth, L., *Disaster management and first aid elements*, Focus Publishing House, Petroșani, ISBN 978-973-677-323-5 (2018).
- www.meteoalarm.eu - information on extreme weather phenomena occurring on the European continent

## Pipe manufacturing process noise and vibration determination case study

Anișoara Corăbieru, Elena Mihalache, Mihai-Adrian Bernevig-Sava,  
Nicoleta-Monica Lohan\*

*“Gheorghe Asachi” Technical University, Bv. Dimitrie Mangeron, no.67,  
Iasi, Romania, 700050*

---

### Abstract

Due to the continuous developments in both science and technology, arises a high importance in organizing human activity at the workplace. Two of the most aggressive factors in the workplace are noise and vibration. The noise problem is quite prevalent today because there are a lot more jobs available in industries with a high level of hazard, and so is the number of exposed workers. The purpose of this paper is to analyze the noise and vibration levels in the pipes manufacturing process measured at SC Pipes SRL from Iasi. Following the field measurements taken in the factory, it has surfaced that in some sections, the noise level has exceeded the maximum level of exposure set in Government Decision (GD) 493/2006. Regarding the vibration exposure measurements, it was found that all measurements were within exposure levels set in (GD) 1876/2005.

*Keywords:* noise levels, vibrations levels, pipes manufacturing

---

### 1. Introduction

The continuous development of industrial technology led to a more focused organization of human activity at the workplace. Noise and vibration represent some of the most aggressive physical factors in the workplace. The noise and vibration problems are still prevalent, altho, recently, the number of workers exposed have diminished thanks to the replacement of obsolete machines and equipment that produced intense noise with modern ones, where these pollutants are, usually, within allowed limits (Munteanu 2007).

Sound represents mechanical vibration propagating through an elastic gaseous, liquid or solid medium through which the source energy is transferred by progressive sound waves. Whenever an object moves or vibrates, a small proportion of the energy involved is lost to the environment in the form of sound (Kovacs 2017). Noise is an unwanted sound that is defined as a mixture of sounds, strong, discordant, unpleasant, being characterized by intensity (dB) and frequency (Hz). Noise and vibration are generally accepted, due to the professional obligations, but, in most cases, humans will carry on doing their work ignoring ambient noise and vibration (Munteanu 2007). Noise is a major problem for the work force, causing hearing loss, discomfort, sleep disorders, fatigue and hypertension. Although extra-auditory effects of exposure to high noise levels have been reported, noise induced hearing loss has been recognized for a long time as a primary effect of excessive noise exposure (Hong et.al, 2013). With the increase in intensity, noise is felt and can have an adverse effect on a person's professional performance. An unexpected or intermittent noise bothers more than a continuous one, and high pitch noises are more bothering than low frequency ones (Munteanu 2007).

Industrial vibrations are an oscillatory type of movement of solid bodies in an elastic environment, these can be found in most work environments and, like noise, have a negative effect on human body functions (Palmer and Bovenzi 2015). In practice, vibration studies gain a growing weight, due to increasingly prevalent trends (Zhao and Schindler 2014, <http://www.medtorrents.com>), like: (i) equipment with higher performance, higher working speeds and higher dynamic stability; (ii) making buildings as light and safe as possible; (i) protecting human operators. Due to increased power and working speeds of equipment, through the development of modern work techniques, a varied

---

\* Corresponding author. Tel.: +0-074-283-4256;  
E-mail address: monica.lohan@yahoo.com

number of sources of noise and vibration have emerged, which led to an increase in the number of persons exposed. Occupational exposure to vibration has many forms and quite frequent in the population. Vibrations can have adverse effects to human health which can manifest through rheumatological afflictions (Palmer and Bovenzi, 2015) or musculoskeletal disorders (Charles et al., 2018). By initiating measures to improve conditions in the work health and safety field, directives have been elaborated on specific areas, stipulating minimum requirements to ensure an optimal level of protection for workers (Kovacs 2017).

Risk identification and assessment is required to determine the protective equipment the workers are required to wear (Ivascu et al., 2014, Moraru et al. 2013), followed by proper use of equipment training (Darabont et al., 2017a, Babut et al., 2011). The correct implementation of the standards in effect (Darabont et al., 2017b, Bejinariu et al. 2017a) is also required.

In this context, the paper analyses the level of noise and vibration in the pipe manufacturing process. For this purpose, vibration measurements were made on the straightening machine, the analyzed area – the drawing roller area and the tube forming area, as well as the noise measurements in the first section of the analyzed company.

## **2. Methodological approach**

Research has begun in the context sketched by competition, based on the idea of profit and sustainable development that imposes limitations through regulation and standards on noise and vibration, which involves additional cost; so, the context is previously the fierce confrontation between the idea of profit and the costs caused by the reduction of noise and vibration. The area of application is in the metallurgical industry, mainly in pipe making, which is under pressure of sustainable development (Corăbieru 2009).

The methodological approach was based on explanations and understanding, and, the main epistemological references of the paper being:

- the interpretativeist paradigm – to understand reality;
- the constructivist paradigm – emphasizing on building in anticipation of some tendencies;
- the positivist paradigm, used as an exception for deductive explanation (in relation to the theory).

As an epistemological approach, the paper has concluded between ethical and emical as follows:

- through the ethical approach, the general characteristics of noise and vibrations are invoked (intensity, frequency), by identifying the specific characteristics for each analyzed work in order to highlight the elements of general applicability (accepted level of noise, level accepted by vibrations);
- through the eco-type approach, the importance of the measured and analyzed noise and vibration characteristics were highlighted for each work station from the technological work flow, identifying the specific levels in the different groups of activities carried out in the pipe manufacturing process emphasizing the interpretative comparative side.

The two approaches are not entirely in opposition to each other, being presented during complementary research, relying on each other.

The methodological support for the study was provided by the specialized literature presented by (Mihai-Adrian et al., 2017, Darabont et al., 2017, Babut et al., GD 493/2006, GD 1876/2005):

- fundamental works by specialized personnel from home and abroad;
- periodical publications, analytical and informative;
- legislative acts of the Government of Romania;
- statistical yearbooks, official reports;
- European environmental directives;
- noise and vibration current legislation.

The research techniques were mainly based on comparative analysis, change analysis, prognosis and optimization of the equipment design on the technological flow of pipe making, modelling and simulation in the design of pipe-type products in order to achieve an explanatory and predictive construction.

The method plan is based on the inductive and the deductive method by mixing the qualitative and the quantitative approach.

## **3. Case study**

The current paper analyses existing noise and vibration in the SC PIPES SRL company, a medium sized company with up to 300 employees and a yearly turnover of over 10 million €. Within the company, the pipe and profile making processes were followed and the physical emissions were measured and analyzed, with emphasis on determining the noise and vibration levels (Corăbieru and Minciună, 2018).

SC PIPES SRL manufactures steel longitudinally welded pipes from hot or cold-rolled strip, on German, Russian and Italian lamination lines. The company also runs cold rolled profiles, has high-quality technologies and its own research center.

The SC PIPES SRL company includes of 6 sections: Section I – 5 production halls, Section II - 8 production halls: Section III - 6 halls: Section IV - 11 halls, Section V - 5 halls: Section VI - 2 halls.



### 3.1. Determining the vibration level

Measuring the vibration level was done in the straightening machine and in the pipe formation areas. The straightening machine (Fig 1a) is an assembly, and, is part of the rolling line; the ribbon is straightened in order to obtain a correct sizing line and to avoid defects or tears. The workers that are handling this machine are subjected to noise and vibration, especially hand and eye protection (Bejinariu et al., 2017b).

In this sense, vibration determinations were made on the drawing rollers. Vibration measurement bulletin for the workplace: the straightening machine is shown in Fig. 1 (b).



Inspectia Muncii  
 Centrul de Monitorizare a Unitatilor cu Risc  
 Profesional- Criscior  
 Abilitarea Ministerului Sanatatii nr. 19710 / 24.09.1999

**BULETIN DE DETERMINARI NR. 25 /**

Unitatea: SC PIPES SRL

Locul de munca: **MASINA DE INDREPTAT**  
 Iluminatul natural (prin ferestre) si artificial (fluorescent).  
 Procesul de productie s-a desfasurat in conditii normale.  
 Timp de lucru 8 ore.

Nr. ord.	Locul de munca	Noxa	Metoda de masurare	Timp de expunere	Aparat folosit	Valoare masurata	Valoare admis
1		Vibrati pe axa Z	Momentan	8 ore	SILO 800	0,36 m/s <sup>2</sup>	1,15 m/s <sup>2</sup>
2		Vibrati pe axa X	Momentan	8 ore	SILO 800	4 m/s <sup>2</sup>	5 m/s <sup>2</sup>

**CONCLUZII:**  
 La punctele nr. 1 si 2 se vor respecta prevederile art. 13 si 15 din HG nr. 1876/2005.

Determinarile s-au facut in prezenta urmatoarelor persoane:

DIRECTOR  
 Ing. Sabau Radu  
 EXECUTANT  
 Ing. Sabau Radu  
 INTOCMIT  
 Ing. Sabau Radu

REPREZENTANT UNITATE  
 Ing. Minciuna Gheorghe

Fig.1. Work place vibration measurements: the straightening machine (a) and the calibration bulletin (b)

The measuring method used was: momentary, with an exposure time of 8 hours. The vibration measurements were made on the Z and X axis. No exceedances for vibrations were found, however, compliance with HG 1876/2005, art. 13 and 15 was recommended.

The machine's rolling speed gradually increases with each strip deformation step. Due to the speed increase on each step, there are noises and vibrations that need to be diminished or eliminated if possible. If the machine tuning isn't done properly, the noise and vibration levels increase and can cause professional illness, discomfort, fatigue, stress, etc.

In this section, vibration measurements were made using the momentary measurement method, with an exposure time of 8 hours. The vibration measurement was carried out on the Z and X axis. Figure 2 shows the analyzed work area (a) and the vibration test report (b). No exceedances for vibrations were found, however, compliance with HG 1876/2005, art. 13 and 15 was recommended.





**Inspekția Muncii**  
**Centrul de Monitorizare a Unităților cu Risc**  
**Profesional - Crisicior**  
Abilitarea Ministerului Sănătății nr. 19710 / 24.09.1999

**BULETIN DE DETERMINARI NR. 25 /**

**Unitatea: SC PIPES SRL**

Locul de munca: Bariu - formare a țevii  
Iluminatul natural (prin ferestre) și artificial (fluorescent).  
Procesul de producție s-a desfășurat în condiții normale.  
Timp de lucru 8 ore.

Nr. crt.	Locul de munca	Noxa	Metoda de masurare	Timp de expunere	Aparat folosit	Valoare	
						masurat	admis
1		Vibrații pe axa Z	Momentan	8 ore	SLD 800	1,0 m/s <sup>2</sup>	1,15 m/s <sup>2</sup>
2		Vibrații pe axa X	Momentan	8 ore	SLD 800	4,5 m/s <sup>2</sup>	5 m/s <sup>2</sup>

**CONCLUZII:**  
La punctele nr.1 și 2 se vor respecta prevederile art.13 și 15 din HG nr.1876/2005.

Determinările s-au făcut în prezența următoarelor persoane:

**DIRECTOR**  
ing. Sabau Radu

**EXECUTANT**  
ing. Sabau Radu

**INTOCMIT**  
ing. Sabau Radu

**REPREZENTANT UNITATE,**  
**ing. Minciuna Gheorghe**

Fig. 2. Analysed work area: (a) the pipe forming area; (b) vibration measurement bulletin for the pipe forming area work station

### 3.2. Determining the noise level

Noise measurement have were taken in section 1, work station and sales service. Resulting from these measurements, it was concluded that there were exceedances of noise levels and that there were some jobs in which the exposure was over the admitted levels. In these places, employee activity was forbidden according to HG 493/2006. Fig. 3 contains the determination bulletin.

**DIRECȚIA DE SĂNĂTATE PUBLICĂ IAȘI**  
Strada VASILE CONȚA nr. 2-4  
Tel. 0232/ 210900 centrală, 0232/271687, fax nr. 0232/ 241933  
e-mail: dshp@diplian.ro, www: diplian.ro

Serviciu: Evaluare factori de risc din mediul de viață și muncă  
Compartiment: Medicină Muncii  
Operator de date cu caracter personal nr.11730

**BULETIN DE DETERMINARE Nr. 52**  
cuprinzând valorile de zgomot înregistrate în data de 07/2017

**la SC PIPES SRL**  
Aparatură folosită: Sonometru integrat "Quest Industries" serie OHOSO110022

Nr. Crt.	LOC DE MUNCĂ	LEQ1	LEQ2	T1	T2	T-t	LEQ(zi)	LMA
I. SECȚIA I								
1	Hala 1 - LPB 11 - pupitru	97,1	72,7	5	3	8	95,06825	87
2	- cabină comandă	89,3	69,9	7	1	8	88,7272	87
3	Hala 2 - Ajustaj gr. Sanfrenat, pat control - ajustaj	98,7	75	7	1	8	98,12273	87
4	- suflare span teavă	117,5	77,2	2	6	8	111,4806	87
5	Hala 2 sud - Colector 220 - pupitru	86,6	69	7	1	8	86,03085	87
6	Hala 2 - Alimentare 220 - pupitru	85,6	64,6	7	1	8	85,02501	87
7	Hala 5 - Linile 30L, 30xU - laminator	82,8	63	7	1	8	82,22657	87
II. SECȚIA a II-a								
8	Hala 10 - Ajustaj 89 pat control - op. verif. țevi	89,5	70,1	7	1	8	88,9272	87
9	Hala 11 - RAC 89 - cuptoare	86,9	69,2	7	1	8	86,3306	87
III. Secția Menținută Preventivă, Predictivă, Statii								
10	At. piese schimb - mașină frezat universală	86,2	68	6	2	8	84,97247	87
IV. SECȚIA STATIA								
11	Camera pompelor	90,3	70	3	5	8	86,10734	87
12	Stație compresoare - mijloc sală	88,5	69,6	4	4	8	85,54529	87
13	- atelier reparații	79,3	65	4	4	8	76,44813	87
V. SERV. VANZARI								
14	Hala 9 - Depozit 99 - op. încălzire țevi	81	60,9	4	4	8	78,03193	87
15	Hala 3,4 sud - Depozit 97 - op. încălzire țevi	83,9	65	4	4	8	80,94529	87

Determinările s-au făcut conf. HG 493 / 2006.  
Valorile înscrise sunt necorespunzătoare.

**LEGENDA**

La aceste locuri de muncă s-a depășit nivelul valorii de expunere de la care se declanșează acțiunea. Se impune luarea măsurilor conform HG 493 / 2006.

... La aceste locuri de muncă s-a depășit nivelul valorii limită de expunere. Este interzisă activitatea angajaților în aceste condiții, conform HG 493 / 2006.

... La aceste locuri de muncă valorile se încadrează în limitele normale.

Intocmit: **as.pr.igienă,**

Leonechi Tudora & Tăbăcariu Andrei

Fig. 3. Workplace test report: Section I

### 3.3. Workplace health and safety policy

The core value promoted by SC PIPES SRL is the creation of a healthy work environment that ensures the development of the organization and the professional and personal development of the employees. The company's target is zero accidents. Prevention of Accidents and Occupational Diseases underpins the drafting of the Health and Safety Policy of SC PIPES SRL.

The main concerns for fulfilling the principles of the Health and Safety Policy are:

- Employee awareness regarding accident risk and workplace illness, related to the activities they are involved in and a continuous care for reducing and eliminating risks;
- Health and Work Safety trainings and workshops;
- Emergency situation simulations;
- Continuous employee consultation on workplace safety and health issues;
- Initiatives to motivate the employees in promoting safe working practices and contribution to the creation of safer jobs.

## 4. Conclusions

The measurements yielded the following conclusions:

1.Noise and vibrations aggravate and maintain pre-existing conditions such as anxious obsessions, nerve depression in depressed patients, gastro-duodenal conditions, and especially unexpected noise can cause major seizures and epilepsy.

2.Noise and vibrations directly reduce work capacity by reducing intellectual concentration, lowering precision and efficiency of movements, decreasing or distracting attention, increasing energy expenditure needed to perform a given physical effort, difficulty in perceiving verbal information (orders, assign task) voice and cerebral overload.

3.Measures to combat noise and vibration must be directed to removing or reducing the action of the indicated causes. If it is not possible to carry out radical measures, measures must be taken to isolate and absorb the noise from production. The sound absorbing material must have a maximum absorption coefficient. It is recommended that, where possible, noise work be carried out in the open air.

4.Proper machine balancing can remove the action of noise and vibration factors. It is possible to install on special elastic basis the machines and equipment that cause noise and vibration and at the same time to separate them with a layer of air from other rooms of the building.

5.Interpretation of the determinations carried out at SC PIPES SRL was made in accordance with GD 493/2006 and GD 1876/2005 and it was found that in the case of noise measurements in some workplaces the level of the exposure value at which the action is triggered was exceeded (Section 1 - Hall 2, collector, Hall 2 - 220-desk power station, 30L lines, 30xU-laminator, Hall 11-RAC 89-ovens, pump room, compressor station).

6.Following the interpretation of the results, it was found that some workplaces exceeded the limit value for exposure to noise. Thus, the activity of the employees is forbidden.

7.As far as the results of the vibration bulletins were concerned, it was found that all measurements were within the limits of exposure to vibrations.

## References

- Babut, G.-B., Moraru, R.-I., Lucian-Ionel, C. "Kinney Methods": Useful or Harmful Tools in Risk Assessment and Management Process?, *Proceedings of the 5th International Conference on Manufacturing Science and Education*, Vol II, Sibiu, Romania, p. 315, (2011).
- Bejinariu, C., Darabont, D.-C., Baci, E.-R., Georgescu, I.-S., Bernevig-Sava, M.-A., Baci, C., Considerations on Applying the Method for Assessing the Level of Safety at Work, *Sustainability*, Vol. 9, p. 1263, (2017).
- Bejinariu, C., Darabont, D. C., Baci, E. R., Ionita, I., Sava, M. A. B., Baci, C. Considerations on the Method for Self Assessment of Safety at Work, *Environ. Eng. Manag. J.* Vol. 16, pp. 1395-1400, (2017).
- Charles E.L., Ma C. C., Burchfiel C. M., Don R. G., Vibration and Ergonomic Exposures Associated With Musculoskeletal Disorders of the Shoulder and Neck, *Safety and Health at Work* Vol. 9, pp.125-132, (2018)
- Corăbieru A, Minciună Gh., Determinarea zgomotului și vibrațiilor în procesul de fabricație al țevelor și profilelor, *Lucrare de licență*, Universitatea Tehnică Gh.Asachi din Iasi, 2018
- Corăbieru P, Perfecționarea managementului ciclului de viață al produselor, *Teză de doctorat*, Universitatea Al. I. Cuza Iasi, 2009
- Darabont, D. C., Antonov, A. E., Bejinariu, C. Key elements on implementing an occupational health and safety management system using ISO 45001 standard, *8th International Conference on Manufacturing Science and Education - Trends in New Industrial Revolution*, Vol. 121, UNSP 11007, Sibiu, România, (2017).
- Darabont, D.-C., Moraru, R. I., Antonov, A. E., Bejinariu, C. Managing new and emerging risks in the context of ISO 45001 standard, *Qual.-Access Success*, Vol. 18, pp. 11-14, (2017).

GD 493/2006

GD 1876/2005

Hong O., Kerr M. J., G.L., Poling, Dhar S., Understanding and preventing noise-induced hearing loss, *Disease-a-Month*, Vol. 59, pp. 110–118, (2013)

Ivascu, L., Cioca, L.-I. Opportunity Risk: Integrated Approach to Risk Management for Creating Enterprise Opportunities, *2nd International Conference on Psychology, Management and Social Science*, Vol. 49, pp. 77-80, Newark, USA, (2014).

Kovacs I. Cercetări privind reducerea zgomotului la prepararea substanțelor minerale utile, *Teza de doctorat*, Univ. Tehnică Petrosani, 2017

Mihai-Adrian, B.-S., Iulian, I., Constantin, B., Costin, D. D., Alexandru, L., Marian, C. A., Costica, B. Improving safety in the workplace using checklists legal requirements. *Qual.-Access Success*, Vol. 18, pp. 31-34 (2017).

Moraru, R. I., Babut, G. B., Cioca, L. I. Study of Methane Flow in Caved Goafs Ajacent to Longwall Faces in Valea Jiului Coal Basin, *Geoconference on Science and Technologies in Geology, Exploration and Mining, Sgem*, Vol I, p. 731, (2013).

Munteanu T.R., Poluarea sonoră. Importanța hărților acustice Universitatea „Transilvania” din Brașov, *Buletinul AGIR* nr. 4, 2007

Zhao X., Schindler C., Evaluation of whole-body vibration exposure experienced by operators of a compact wheel loader according to ISO 2631-1:1997 and ISO 2631-5:2004, *International Journal of Industrial Ergonomics*, Vol.44 pp. 840-850, (2014)

[http://www.medtorrents.com/blog/noxe\\_profesionale/2017-03-17-1768](http://www.medtorrents.com/blog/noxe_profesionale/2017-03-17-1768)

## Modern approaches in integrated management systems of quality, environmental and occupational health and safety

Doru-Costin Darabont<sup>a</sup>, Costică Bejinariu<sup>b\*</sup>, Constantin Baciub,  
Mihai-Adrian Bernevig-Sava<sup>b</sup>

<sup>a</sup> INCDPM “Alexandru Darabont”, 35 A, Ghencea Blv., Sector 6, 061692, Bucharest, Romania

<sup>b</sup> “Gheorghe Asachi” Technical University of Iasi, D. Mangeron Blv., no. 67, 700050, Iasi, Romania

---

### Abstract

Releasing of ISO 9001 and ISO 14001 standards in 2015 represents a big step forward in managing quality and environmental issues on an integrated manner, optimizing the resources spent by the organization for this scope. This set of instruments becomes complete by the releasing, in 2018, of ISO 45001 “Occupational health and safety management systems – Requirements with guidance for use”. The new international standard integrates the good practice gained by using former documents, such as ILO-OSH 2001 “Guidelines on occupational safety and health management systems” and OHSAS 18001 “Occupational health and safety management systems – Requirements”.

The strongest point of the triad represented by ISO 9001, ISO 14001 and ISO 45001 is the similar structure of these standards, based on the ISO 10 core clauses of the High Level Structure. This characteristic leads to a high potential to integrate the quality, environmental and occupational health and safety requirements in a single integrated management system.

Due to the novelty of these standards, it is necessary to develop new instruments to help organizations in implementing and assess the performance of the integrated management system.

The paper presents a high level checklist, aimed on auditing an integrated management system based on ISO 9001:2015, ISO 14001:2015 and ISO 45001:2018. This tool could be used for an integral audit, against all three standards, or just for a partial audit, against one or two standards.

In order to optimise the resources allocated for the audits, the checklist should be used together with an IT tool, also elaborated by the authors and described in the paper, which can provide several important functions such as automation of scores, synthesize of the results and digital archiving of the information.

*Keywords:* integrated management systems, occupational health and safety, quality management, environmental management, audit.

---

### 1. Introduction

Releasing of ISO 9001 and ISO 14001 standards in 2015 completed by ISO 45001 in 2018 represents a big step forward in integrated management of quality, environmental and occupational health and safety issues. The strongest point of the triad represented by ISO 9001, ISO 14001 and ISO 45001 is the similar structure of these standards, based on the ISO 10 core clauses of the High Level Structure. This characteristic leads to a high potential to integrate the quality, environmental and occupational health and safety requirements in a single integrated management system.

Considering the novelty of these three standards, the organizations need new instruments to facilitate the implementation and assessing the performance of the integrated management system. The high level checklist could be used for an integral audit, against all three standards, or just for a partial audit, against one or two standards. Also, the checklists could be combined with an IT tool, which can provide several important functions such as automation of scores, synthesize of the results and digital archiving of the information.

---

\* Corresponding author. Tel.: +4-0745-750-286.

E-mail address: cbejinari@tuiasi.ro.

## 2. Overview of the integrated management systems

An integrated management system uses a similar approach of quality, environmental and occupational health and safety (OH&S) issues, optimizing the resources spent by the organization for this scope. It is based on the requirements of the following standards, see Fig.1:

- ISO 9001:2015 - "Quality management systems. Requirements" (with its Romanian version SR EN ISO 9001:2015);
- ISO 14001:2015 – "Environmental management systems – Requirements with guidance for use" (with its Romanian version SR EN ISO 14001:2015) and
- ISO 45001:2018 – "Occupational health and safety management systems – Requirements with guidance for use" (with its Romanian version SR ISO 45001:2018).

ISO 45001 standard replaces OHSAS 18001 standard which has acted as an international standard until 2018, when the new ISO standard has been released.

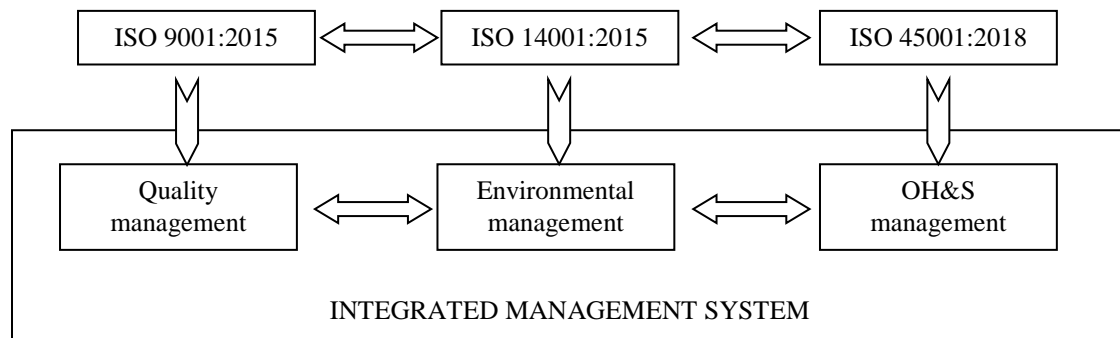


Fig. 1. Structure of an integrated management system

One of the main requirements of the organizations is to benefit by similar procedures for quality and environmental management as well as for OH&S management. In this scope, the structures of standards ISO 9001:2015, ISO 14001:2015 and ISO 45001:2018 are similar and based on the ISO 10 core clauses of the High Level Structure (Annex SL), which brings a common framework for all management systems. The 10 core clauses, common to all three standards, are presented in Table 1.

Table 1. Common structure of the standards, based on Annex SL

No.	Chapter
1	Scope
2	Normative references
3	Terms and definitions
4	Context of the organization
5	Leadership
6	Planning
7	Support
8	Operation
9	Performance evaluation
10	Improvement

Anyhow, there are some particular requirements of each standard which should be considered, such as:

- Requirements for products and services, in case of ISO 9001:2015;
- Environmental objectives and plans for achieving them, in case of ISO 14001:2018, or
- Hazard identification and assessment of OH&S risks, in case of ISO 45001:2018.

Thus, regarding hazard identification and assessment of OH&S risks, the standard requires the organization to “establish, implement and maintain a process for the on-going proactive identification of hazards arising” (SR ISO 45001:2018). As the standard does not recommend a certain method for hazard identification and risk assessment, the organization itself should adopt the method which is most appropriate for its size, territorial structure, type of activity, type of hazards, legal or organizational requirements etc. Generally, organizations prefer the methods considering risk as a result of three dimensions (Băbuț, G.B. et al., 2011). In Romania, a frequently used method for risk assessment is the method developed in 1998 by the National Research and Development Institute on Occupational Safety, which fully responds to the requirements of Government Decision no.1425/2006 regarding the approach of risk assessment (Darabont, D.C. et al., 2017).

### 3. Software tool for auditing the integrated management system

Analyzing the text of the standards, each requirement could be transposed in a specific item. Thus, three distinct high level checklists are obtained:

- Checklist for auditing quality management system;
- Checklist for auditing environmental management system;
- Checklist for auditing OH&S management system.

These checklists could be used together or separately, providing a high flexibility of the system.

Each item of a checklist should be assessed and it will obtain 0, 1 or 2 points, according to the requirement fulfilling level, as follows:

- 0 points, representing a non-conformity and showing that the requirement are not addressed;
- 1 point, representing a partial conformity;
- 2 points, representing a conformity, or showing that the requirements are fulfilled.

The conformity level ( $CL_i$ ) for each checklist is obtained as a percentage of the gained points from the maximum score (considering all the relevant items are noted with 2 points).

The overall conformity level ( $CL$ ), characterising the integrated management system is obtained as the average of the conformity level ( $CL_i$ ) for each checklist used in assessment.

The software tool was elaborated using Microsoft Office Excel, considering the main advantages of this application: large number of users, flexibility, connectivity with Microsoft Word etc.

1	Company:		Auditor(s):	
2	Division/department:			
3	Date:			
4	Checklist for assessing the OH&S management system			
5	Criteria:			
6	ISO 45001			
7	No.	Item	Assessment (Pts.)	
8			0/1/2	
9		<b>1. Context of the organization</b>		
10	1	All relevant issues in relation to organization's OH&S management system were determined.	2	
11	2	All relevant interested parties in relation with organization's OH&S management system were determined.	1	
12	3	The relevant needs and expectation of workers and of other interested parties were identified.	1	
13	4	The scope of the OH&S management system was determined and documented.	2	
14	5	The OH&S management system is established, implemented, maintained and continually improved.	2	
15		<b>2. Leadership and worker participation</b>		
16	6	Top management demonstrates leadership and commitment regarding OH&S management system.	1	
17	7	Top management has established, implemented and maintain an OH&S policy.	2	

Fig. 2. Software tool for auditing the integrated management system

### 4. Conclusion

The strongest point of the triad represented by ISO 9001, ISO 14001 and ISO 45001 is the similar structure of these standards, based on the ISO 10 core clauses of the High Level Structure. This characteristic leads to a high potential to integrate the quality, environmental and occupational health and safety requirements in a single integrated management system, having as a result the optimization of the resources allocated by organization for implementing and maintaining the integrated management system.

The organizations need new instruments to facilitate the implementation and assessing the performance of the integrated management system. The high level checklists could be used for an integral audit, against all three standards, or just for a partial audit, against one or two standards. Also, the software tool provides several important functions such as automation of scores, synthesize of the results and digital archiving of the information.

## References

- Băbuț, G.B., Moraru R.I., Cioca, L.I., *Kinney Methods: Useful or Harmful Tools in Risk Assessment and Management Process*”, 5<sup>th</sup> International Conference on Manufacturing Science and Education on Creative Thinking in Engineering and Academic Education, Proceedings of the 5<sup>th</sup> International Conference on Manufacturing Science and Education (MSE 2011), Vol.II, pp.315, (2011).
- Darabont, D.C., Antonov, A.E., Bejinariu, C., *Key elements on implementing an occupational health and safety management system using ISO 45001 standard*, Proceedings of the 8<sup>th</sup> International Conference on Manufacturing Science and Education - MSE 2017 ”Trends in New Industrial Revolution”, (2017)
- SR ISO 45001:2018 *Occupational health and safety management systems – Requirements with guidance for use* (2018)

## Study on increasing the thermal protection of high-temperature helmets used by firefighters

Ciubotariu-Ana Paul, Bernevig-Sava Mihai-Adrian, Lohan Nicoleta-Monica\*,  
Bejinariu Costica

*“Gheorghe Asachi” Technical University of Iasi, 67 Dimitrie Mangeron Blv.,  
Iasi, 700050, Romania,*

---

### Abstract

Protective helmets are very important components of individual fire-fighting equipment. They have different roles including: protecting the head from throwing objects, protecting from high temperatures or electrical shocks. In order to be used, they must ensure the absorption of shocks in the upper part of the head, to have penetration resistance, to have lateral crush resistance, to provide protection against hot liquids and high temperature resistance. The helmet material has to provide the same properties when is exposed to  $90 \pm 5^\circ\text{C}$  for 20 minutes in the area of the upper head and ear, and at  $180 \pm 5^\circ\text{C}$  for 5 minutes in the area of the neck protector. At the moment, fire-fighting helmets are made of high-quality polymers.

This paper aims to analyse the thermal behaviour of a new material useful for fire-fighting helmets: hot modelling material, under the form of a glass fibre-reinforced bismaleimide composite material, compared to a molded polypropylene injection. Thermal analysis will be performed using differential scanning calorimetry (DSC) and Dynamo Mechanical Analysis (DMA) and the thermal properties of the new material will be highlighted.

*Keywords:* Personal Protecting Equipment, firefighter helmets, bismaleimide, high temperature resistance

---

### 1. Introduction

Personal Protective Equipment (PPE) is the equipment intended to be worn or held by the worker to protect him against the risks that might endanger his health and safety at work, as well as any additional or accessory designed for that purpose, according to GD 1048/2006. PPE is part of the daily routine of all those working in the industry, construction and emergency services staff. Currently, Romania has one of the highest levels of incidents in Europe, with over 4,900 accidents at workplace being reported in 2016, of which 225 were fatal accidents, according to the Labor Inspection report ([www.inspectiamuncii.ro](http://www.inspectiamuncii.ro)).

One of the causes is the inappropriate choice and use of PPE (Bejinariu et al., 2017a). PPE includes the following components required for: head protection, leg protection, face protection, respiratory protection and body protection (Park et al., 2015). It should be noted that the use of protective equipment is the last priority in the process of preventing accidents at work; in principle, reducing or controlling risks at source should prevail (Mihai-Adrian et al, 2017, Babut and Moraru, 2018). Risk assessment is a first step in determining the type of protection required (Ivaşcu et al., 2014, Moraru et al., 2013), followed by the training for an appropriate use of the equipment (Darabont et al., 2017a, Babut et al. 2011), as well as the correct implementation of the standards in force (Darabont et al., 2017b, Bejinariu et al., 2017b).

Combating fire is often described as a very dangerous activity (Ghani et al., 2017). According to statistical data, the dangers that endanger the safety of firemen's life can be divided into several categories, namely: building demolition, flashover explosion, fall from height, electric shock, gas poisoning, road accidents and other accidents (Kang et al., 2016). The probability of meeting high heat environments contributes to the dangers inherent in this occupation. Situations such as "flashovers" and high intensity fire are examples of circumstances in which anti-fire personnel can expect to face a high level of radiant heat flow. To ensure adequate protection against bodily injury and fire blazes, PPE

---

\* Corresponding author. Tel.: +0-074-283-4256.  
E-mail address: monica.lohan@yahoo.com



is designed to isolate the wearer from the dangers of the environment and ensure the efficient performance of the work duties (Vigneswaran, and Arulmurugan 2014).

Appropriate head protection equipment is particularly important for the safety and protection of firefighters when they engage in small or large fires (Bălan et al, 2011). The helmet is designed to protect the head from flying objects, explosions, high temperatures, electrical shocks, and chemicals. Those helmets must meet certain specific thermal, shock, penetration or abrasion resistance requirements, in accordance with current standards.

In Romania, firefighting helmets in buildings and other structures must be tested and meet the mandatory performance requirements in accordance with SR EN 443:2008: shock absorption in the upper area of the head, penetration resistance, side impact resistance, radiant heat resistance, protection against hot liquids, as well as heat resistance. In general, a helmet consists of a cap and harness and other accessories. The cap is the visible part of the helmet made of materials resistant to temperature, vibration, impact and humidity. The most commonly used cap materials are high density polyethylene (HDPE), acrylonitrile-butadiene-styrene copolymer (ABS) or polycarbonate (PC).

Nowadays, new studies are being carried out and new materials are sought to improve the thermal and mechanical properties of the helmets. A good candidate for making the helmet cap is bismaleimide. This new material presents a number of advantages such as: high thermal stability, nonvolatility and low cost (Ursache et al., 2012). The purpose of this paper is to present the thermal properties of a new material, a glass fiber reinforced bismaleimide composite material (BISM COMP) obtained by some of the authors of this work, a material used to manufacture the helmet caps used by firefighters.

## 2. Experimental details

The material analyzed in the present paper was obtained by hot molding process, as a composite of glass fiber reinforced bismaleimide. The bismaleimide resin precursor (BMI) were prepared by reaction of 4,4-bismaleimidodiphenylmethane with 4,4-diaminodiphenyl methane. Silica cloth was impregnated with a 50 wt. % solution of BMI pre-polymer in N-methylpyrrolidone and allowed to dry for 24 h at room temperature and in a circulating air. The pre-pregs dimension 100x100 mm were packed over the female part of the steel mold coated with silicone release agent. The male counterpart of the mold was placed between the preheated plates (140°C). The first laminate samples were obtained in sheets consisting of a single layer and by pressing several layers followed by heating the samples were allowed to cool down to room temperature gradually under a pressure of 10 Kg/cm<sup>2</sup> and the second type, of multilayer samples, were obtained (Ciubotariu-Ana et al., 2018) Thermal analysis was performed by differential scanning calorimetry (DSC) and mechanical-dynamic analysis (DMA). Tests were performed on two types of samples: samples from a fire-fighting helmet bought from commerce (HDPE) and samples made from glass fiber-reinforced bismaleimide composite (BISM COMP).

For DSC analysis, the DSC F3 Maia calorimeter (Fig. 1) supplied by NETZSCH, with a sensitivity of <1 μW, temperature accuracy: 0.1 K and enthalpy accuracy - generally <1%, was used. The device was calibrated with Bi, In, Sn, Zn and Hg.

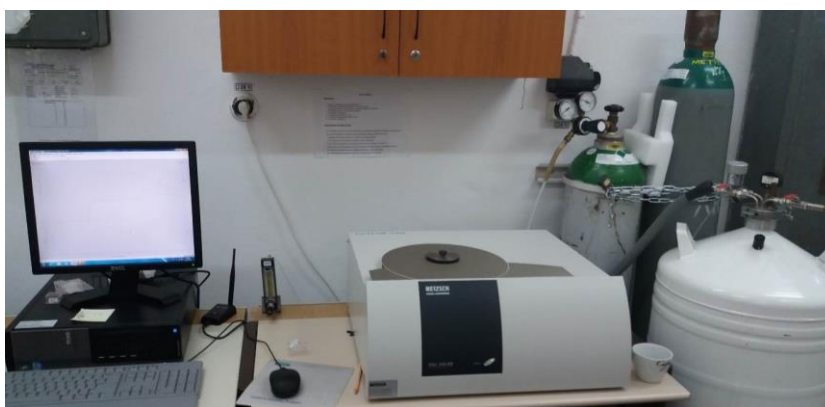


Fig. 1. DSC calorimeter used for experiments

The measurements were performed under Ar-protective atmosphere using corresponding correction curves. The DSC data was evaluated with Proteus software provided by NETZSCH. Small samples with a maximum mass of 25 mg were cut. After they have been cleaned from impurities, they were subjected to controlled heating with a 10K/min heating rate up to 400K for the HDPE sample, and 450K for the BISM COMP sample.

For DMA analysis, a dynamic mechanical analyzer (DMA) type DMA 242 Artemis supplied by NETZSCH was used (Fig.2), with a force resolution of 0.0005 N, amplitude range:  $\pm 0.1$  to 240 μm and amplitude resolution: 0.0005 μm using a three-point-bending specimen holder.



Fig. 2. DMA analyzer used for experiments

For analysis, a frequency of 1Hz and an amplitude of 20  $\mu\text{m}$  were used. Experiments were conducted in inert gas atmosphere and consisted of controlled heating up to 420 K for the HDPE sample, and 470 K for the BISM COMP sample.

### 3. Results and discussions

The DSC thermogram illustrating the heating behavior of the HDPE sample is shown in Fig. 3.

During heating, it can be seen that the sample taken from a helmet bought from commerce has a minimum endotherm at 383.4 K, which is attributed to the melting of the material. For common commercial grades of medium and high density polyethylene, the melting point is typically between 280 and 300 K (Chianelli-Junior et al., 2013). The amount of heat absorbed during this transformation is about 1 J/g.

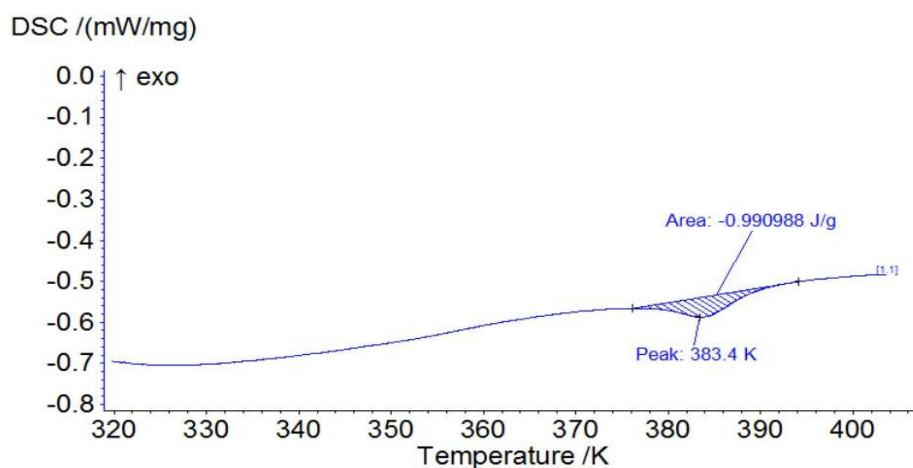


Fig. 3. DSC thermogram recorded during heating for the HDPE sample

In case of heating the sample made from BISM COMP, Fig. 4, the DSC thermogram shows no deviation from linearity that could suggest the presence of a transformation in the temperature range under analysis. It can be argued that the BISM COMP material is thermally stable up to 450 K

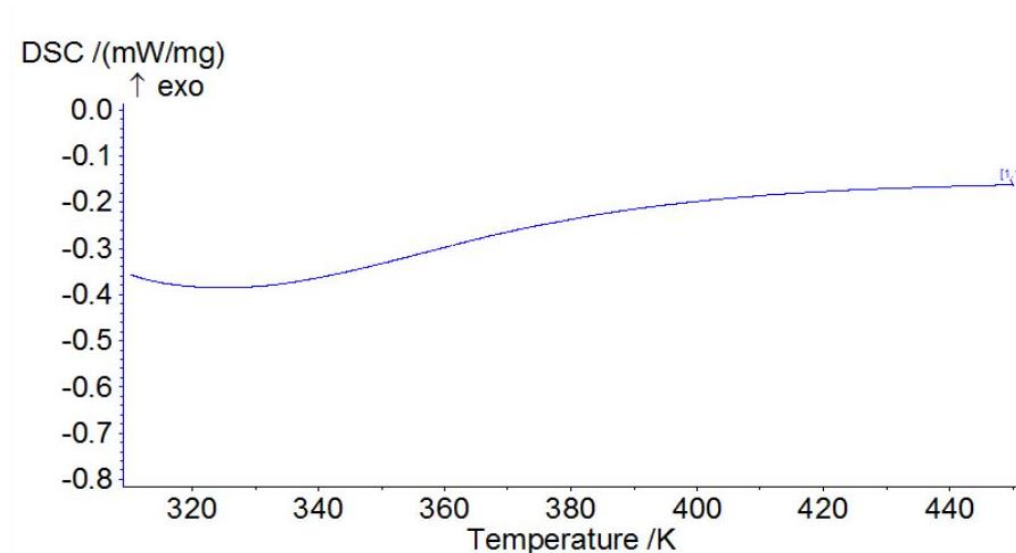


Fig. 4. DSC thermogram recorded during heating for the BISM COMP sample

To verify the visco-elastic behavior of the analyzed samples, DMA experiments were performed. For the analysis was chosen the variation of storage modulus ( $E'$ ), and the internal friction ( $\tan \delta$ ) with temperature. In Fig. 5 shows the variation of module  $E'$  for the two analyzed samples. For a better understanding of the dynamo-mechanical properties, an overlap of the elastic modulus ( $E'$ ) was realized for the two samples.

From Fig. 5 it can be seen that the modulus  $E'$  value for the BISM COMP sample has values approximately 9 times higher than HDPE. Also, during heating, the sample retains its stiffness in the temperature range of 300-450 K without taking any softening, a requirement imposed to protective helmets. The high levels of the elasticity modulus (about 11 GPa) of the resins bismaleimide are similar to those reported in the literature (Shibata and Hashimoto, 2017).

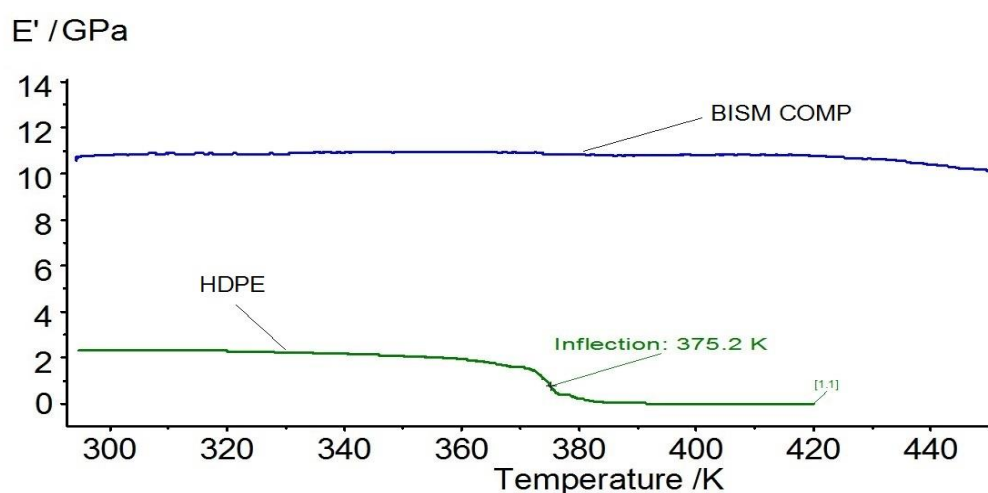


Fig. 5.  $E'$  variation with temperature recorded during heating for the HDPE and BISM COMP samples

On the other hand, the HDPE sample shows a decrease in the modulus between temperatures of 370 -380 K, confirming the recorded melt on the DSC thermogram in Fig. 3. Analysis of  $\tan \delta$  curves is very useful in determining of the performance to stress and temperature of the samples. Fig. 6 shows the  $\tan \delta$  curves corresponding to HDPE and BISM COMP samples.

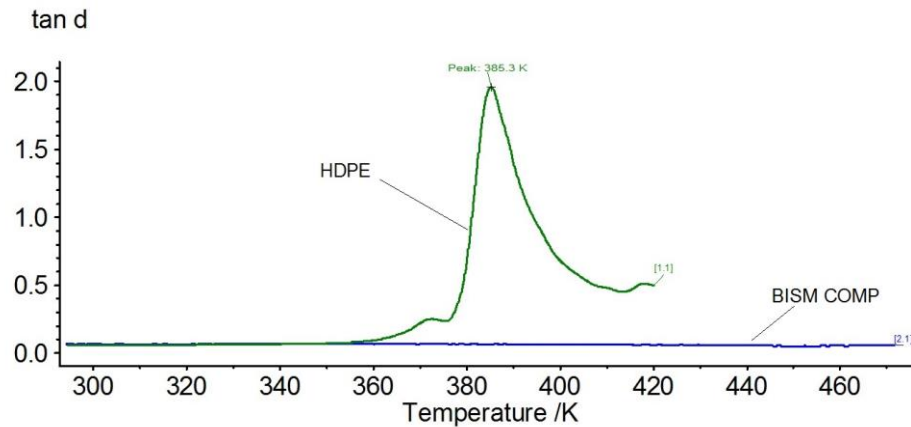


Fig. 6. Tan  $\delta$  variation with temperature recorded during heating for the HDPE and BISM COMP samples

It is clear that in the temperature range studied between 300 and 460 K, the variance of tan  $\delta$  for the BISM COMP sample shows low values. This can be attributed to improved interactions and modified stress transfer. It also explains the values obtained for stiffness by the BISM COMP material (Tian et al, 2017).

It follows that BISM COMP does not undergo any transformation in the area of the analysed temperature while the HDPE sample exhibits a maximum at 385 K, attributed to the melting of the material, according to the data obtained in Fig. 3 and 5.

#### 4. Conclusions

In this paper we examined the thermal and mechanical dynamics of two samples of material for the fire helmets: a sample taken from a helmet bought from commerce, and a sample of a new material developed by the authors. In summary, the following conclusions were drawn:

- the new material, BISM COMP, exhibits improved thermal properties compared to the materials on the market, proving a superior thermal behaviour;
- during DSC analyses the BISM COMP sample did not show any phase transformation in the temperature analysed field, being thermally stable;
- during DMA analyses, the BISM COMP sample showed an elastic modulus approximately 9 times greater than the sample with which it was compared;
- improved thermal performance makes BISM COMP a good candidate for developing the cap of fire helmets to improve the user safety to high temperatures.

#### References

- Babut, G.B., Moraru, R.I., Occupational risk assessment: imperatives for process improvement, *Quality - Access to Success*, Volume 19, Issue 166, pp. 133-144, 2018.
- Babut, G.-B.; Moraru, R.-I.; Lucian-Ionel, C. "Kinney Methods": Useful or Harmful Tools in Risk Assessment and Management Process?, *Proceedings of the 5th International Conference on Manufacturing Science and Education*, Vol II, Sibiu, Romania, pp. 315, (2011).
- Bălan, C., Serban, M., Domșa, C., Măroiu, A., Dispozitive portabile de pulverizare a apei, *Buletinul pompierilor*, Vol. 1, pp. 90-94, (2011)
- Bejinariu, C., Darabont, D.-C., Baci, E.R., Georgescu I.S., Bernevig-Sava, M.-A., Baci, C., Considerations on Applying the Method for Assessing the Level of Safety at Work, *Sustainability*, Vol. 9, pp. 1263, (2017)
- Bejinariu, C.; Darabont, D. C.; Baci, E. R.; Ionita, I.; Sava, M. A. B.; Baci, C. Considerations on the Method for Self Assessment of Safety at Work, *Environ. Eng. Manag. J.* Vol. 16, pp. 1395 –1400, (2017).
- Chianelli-Junior, R., Reis, J.M.L., Cardoso, J.L., Castro, P.F., Mechanical Characterization of Sisal Fiber-Reinforced Recycled HDPE Composites, *Materials Research*, Vol.16(6), pp. 1393-1397, (2013)
- Ciobotariu-Ana, P., Micu, C. A., Lohan, N. M., Pricop, B., Bujoreanu, L. G., Bejinariu, C. Thermal Analysis of a New Glass Fiber-Reinforced Bismaleimide Composite Material Used for Firefighter Helmets, *IOP Conf. Series: Materials Science and Engineering* Vol. 374, 012022, (2018)
- Darabont, D.-C., Moraru, R. I., Antonov, A. E., Bejinariu, C. Managing new and emerging risks in the context of ISO 45001 standard, *Qual.-Access Success*, Vol. 18, pp. 11-14, (2017).

- Darabont, D. C., Antonov, A. E., Bejinariu, C. Key elements on implementing an occupational health and safety management system using ISO 45001 standard, *8<sup>th</sup> International Conference on Manufacturing Science and Education - Trends in New Industrial Revolution*, Vol. 121, UNSP 11007, Sibiu, România, (2017).
- Ghani, S., ElBialy, E.M.A.A., Bakochristou, F., Gamaledin, S.M.A., Rashwan, M.M., The effect of forced convection and PCM on helmets' thermal performance in hot and arid environments, *Applied Thermal Engineering*, Vol.111, pp. 624–637, (2017)
- HG 1048/2006
- Ivascu, L.; Cioca, L.-I. Opportunity Risk: Integrated Approach to Risk Management for Creating Enterprise Opportunities, *2<sup>nd</sup> International Conference on Psychology, Management and Social Science*, Vol. 49, pp. 77–80, Newark, USA, (2014)
- Kanga, R., Fua G., Yan, H., Analysis of the case of fire fighters casualties in the building collapse, *Procedia Engineering* Vol. 135, pp. 343 – 348, (2016)
- Mihai-Adrian, B.-S., Iulian, I., Constantin, B., Costin, D. D., Alexandru, L., Marian, C. A., Costica, B. Improving safety in the workplace using checklists legal requirements. Qual.-Access Success, Vol. 18, pp. 31-34 (2017).
- Moraru, R. I.; Babut, G. B.; Cioca, L. I. Study of Methane Flow in Caved Goafs Ajacent to Longwall Faces in Valea Jiului Coal Basin, *Geoconference on Science and Technologies in Geology, Exploration and Mining, Sgem*, Vol I, pp. 731, (2013).
- Park, H., , Kim, S., Morris, K., Moukperian, M., Moon Y., Stull J., Effect of firefighters' personal protective equipment on gait, *Applied Ergonomics*, Vol.48,pp.42-48, (2015)
- Shibata, M., Hashimoto, Y., High performance thermosetting bismaleimide resins via thiolmaleimide “click” reaction, *European Polymer Journal*, Vol. 93, pp. 561-571, (2017)
- SR EN 443:2008
- Tian, S., HE, H., Yu, P., Zhou, L., Luo, Y., Jia, D., Sustainable utilization of waste printed circuit boards powders in HDPE-wood composites: Synergistic effects of multicomponents on structure and properties, *Journal of Cleaner Production*, Vol.164, pp. 840-847, (2017)
- Ursache, O., Gaina, C., Gaina, V., Musteata, V.E., High performance bismaleimide resins modified by novel allyl compounds based on polytriazoles, *J Polym Res*, Vol. 19, pp. 9968, (2012)
- Vigneswaran, G., Arulmurugan, L., Improving Thermal Comfort in Industrial Safety Helmet using Phase Change Material, *International Journal of Scientific Engineering and Technology Research*, Vol. 3, pp.0712-0715, (2014)
- <https://www.inspectiamuncii.ro> (accessed in August 12, 2018)

## Selection and verification of personal protective equipment in the context of current legal requirements

Bernevig-Sava Mihai-Adrian<sup>a</sup>, Darabont Doru Costin<sup>b</sup>, Lohan Monica<sup>a</sup>, Mihalache Elena<sup>a</sup>,  
Bejinariu Costică<sup>a,\*</sup>

<sup>a</sup> "Gheorghe Asachi" Technical University of Iasi, D. Mangeron Blv., no. 67, 700050, Iasi, Romania

<sup>b</sup> INCDPM "Alexandru Darabont", 35 A, Ghencea Blv., Sector 6, 061692, Bucharest, Romania

---

### Abstract

"Decision no. 1048 of 9 august 2006 on the minimum safety and health requirements for the use by workers of personal protective equipment at work "may be considered as the legal provision which makes available, in its annexes, the risk assessment tool for the selection of individual equipment protection in order to achieve "the identification of the individual protective equipment necessary for the work stations in the unit and the elaboration of the necessary equipment for the workers with the individual protective equipment" (according to point 20, paragraph (1), article 15 of the Methodological Rules in 11 october 2006 on the application of the provisions of the Law on safety and health at work no. 319/2006).

Implementation in april 2018 of Regulation no. 425 of 9 march 2016 on personal protective equipment and repealing Council Directive 89/686 / EEC, provides elements that will allow "to monitor the maintenance, handling and proper storage of personal protective equipment and their replacement by the deadlines" with the requirements of point 19, paragraph (1) of article 15 of the Methodological Rules for the application of the Law on safety and health at work no. 319/2006.

**Keywords:** safety and health requirements, personal protective equipment, monitor the maintenance, replacement.

---

### 1. Introduction

The multitude of legal provisions in different areas such as employment relationships, occupational health, occupational safety and health or procurement puts the employer in difficulty when it comes to the correct and natural order of steps to be taken to comply with the requirements of current legislation.

If we consider the moment of employment, the Labor Code - republished, dated 24 January 2003, adopted by Law no. 53, art. 27, paragraph (1) clearly states that "A person may be employed only on the basis of a medical certificate, which establishes that the person concerned is fit to perform that work." Paragraph 2 adds that "Non-observance of the provisions of paragraph (1) entails the nullity of the individual employment contract. "

### 2. Evaluation for the selection of personal protective equipment

The employer, having the obligation to implement occupational safety and health measures and on the principle of "priority adoption of collective protection measures against individual protection measures", leads to the need to carry out an assessment before choosing individual equipment protective. This assessment, even if required by the Decision 1048 of 2006 and according to Art. 14, paragraph (2) comprises:

"(a) analysing and assessing risks that cannot be avoided by other means;

(b) defining the characteristics that the personal protective equipment must possess in order to be effective against the risks referred to in a) taking into account any risks that the equipment itself may create;

(c) comparing the characteristics of the individual protective equipment available with the features set out in b) ", she initiates in the first instance from a document and knowledge of the actual conditions of the work of the worker, as a working position and is complementary to the completion of the annex no. 3 of Decision no. 355 of 2007 on the health

---

\* Corresponding author. Tel.: +4-0745-750-286.

E-mail address: cbejinari@tuiasi.ro



surveillance of workers. This appendix requires, prior to hiring and then periodically, the indication of the risks to which the worker is exposed, the description of the workspace, the level of effort, the overloading, the chemical, the biological, the carcinogen, the dust or the radiation that the worker comes into contact with, the microclimate as well as the means of collective protection and individual protection.

Implementation in April 2018 of the Regulation no. 425 of 9 March 2016 on personal protective equipment and repealing Council Directive 89/686 / EEC, provides for the elements to be used to monitor the maintenance, handling and proper storage of personal protective equipment and their replacement by the deadlines, with the requirements of point 19, paragraph (1) of Article 15 of the Methodological Rules for the Application of the Law on Safety and Health at Work no. 319/2006.

This Regulation, in Annex II: Essential Health and Safety Requirements, point 1.4. The manufacturer's instructions and information clearly state that "besides the manufacturer's name and address, the instructions to be provided with the PPE must include all relevant information on:

- (a) instructions for storage, use, cleaning, maintenance, repair and disinfection. The cleaning, maintenance or disinfection products recommended by manufacturers must not have any negative effects on PPE or on users if used in accordance with the relevant instructions;
- (b) the performance of the relevant technical tests to verify the levels or categories of protection offered by the PPE;
- (c) where appropriate, the accessories that can be used with the PPE and the characteristics of the corresponding spare parts;
- (d) where appropriate, the classes of protection appropriate to the different risk levels and the appropriate limits of use;
- (e) where appropriate, the month and year or period of end of use of the PPE or some of its components;
- (f) where appropriate, the type of packaging suitable for transport;
- (g) the meaning of any marking (see paragraph 2.12);
- (h) the risk against which PPE is intended to protect;"

As regards the setting of deadlines for the decommissioning of PPE, Regulation no. 425 specifies in point 2.4. in Annex II that 'if it is known that the projected performance of the new PPE may be significantly affected by the wear and tear phenomenon, an indelible and unambiguous marking indicating the month shall be affixed to each of the PPE placed on the market and their packaging the year of manufacture and / or, if possible, the month and year of use.

If the manufacturer cannot provide guarantees on the useful life of the PPE, his instructions must provide all the information necessary for the user or purchaser to reasonably determine the month and year of use, taking into account the quality level of the PPE. model and the specific conditions of storage, use, cleaning, maintenance and maintenance. If it is found that the process of considerable and rapid degradation of PPE performance may be caused by the wear and tear resulting from the periodic use of a cleaning process recommended by the manufacturer, the latter must, if possible, apply to each of the PPE introduced a mark on the market indicating the maximum number of cleaning operations that can be performed before the equipment has to be checked or cancelled. If such a marking is not applied, the manufacturer must provide that information in the instructions."

For PPE bearing one or more identification or indicators directly or indirectly related to health and safety, such markings or indicators should preferably take the form of harmonized pictograms or ideograms. They must be perfectly visible and legible and thus remain throughout the foreseeable useful life of the PPE. In addition, such markings must be complete, precise and comprehensible so as to prevent any misinterpretation. In particular, where such markings include words or phrases, the latter must be written in a language that can be easily understood by consumers and other end-users, as determined by the Member State in which the PPE is available on the market.

If the PPE is too small to allow the application of all or some of the required markings, the relevant information must be stated on the manufacturer's packaging and instructions."

For electrical insulating equipment, the manufacturer's instructions shall indicate in particular the exclusive use to which those types of PPE were intended and the nature and frequency of the dielectric tests to which they are subject during their useful life "and for protective equipment against substances and mixtures that are harmful to health and harmful biological agents "the manufacturer's instructions must also indicate the storage deadline of the new filters kept in their original packaging" and "the manufacturer's instructions must contain, in particular, a explanation of the codes (if necessary), a detailed description of the standard tests and all relevant information for calculating the maximum allowable wearing time under the various foreseeable conditions of use."

These provisions contained in Regulation no. 425 of 9 March 2016 allows for the schematic design of the risk assessment process for the selection of the individual protective equipment (Fig. 1) as well as the calculation, the determination of the duration of standard use not only "in terms of expenditure planning". (Antonov et al., 2013; Darabont et al., 2017)

The calculation of the normal use time may be influenced by the nature of the activity carried out or the properties of the individual protective equipment starting from disposable, up to eight hours / a work shift in certain environments up to four or five years in the case of helmets. With the exception of single-use protective equipment, the other categories may be normalized by a calculation that calls into question the time (storage or maximum permissible use), a value component influenced by the risk factors / hazards arising in the performance of the task and which can be eliminated / diminished by PPE and can lead to a degree of wear plus values related to maintenance tracking (proper washing and decontamination), handling (training of workers and proper use) and adequate storage (conditions to be met comply with the manufacturer's instructions).

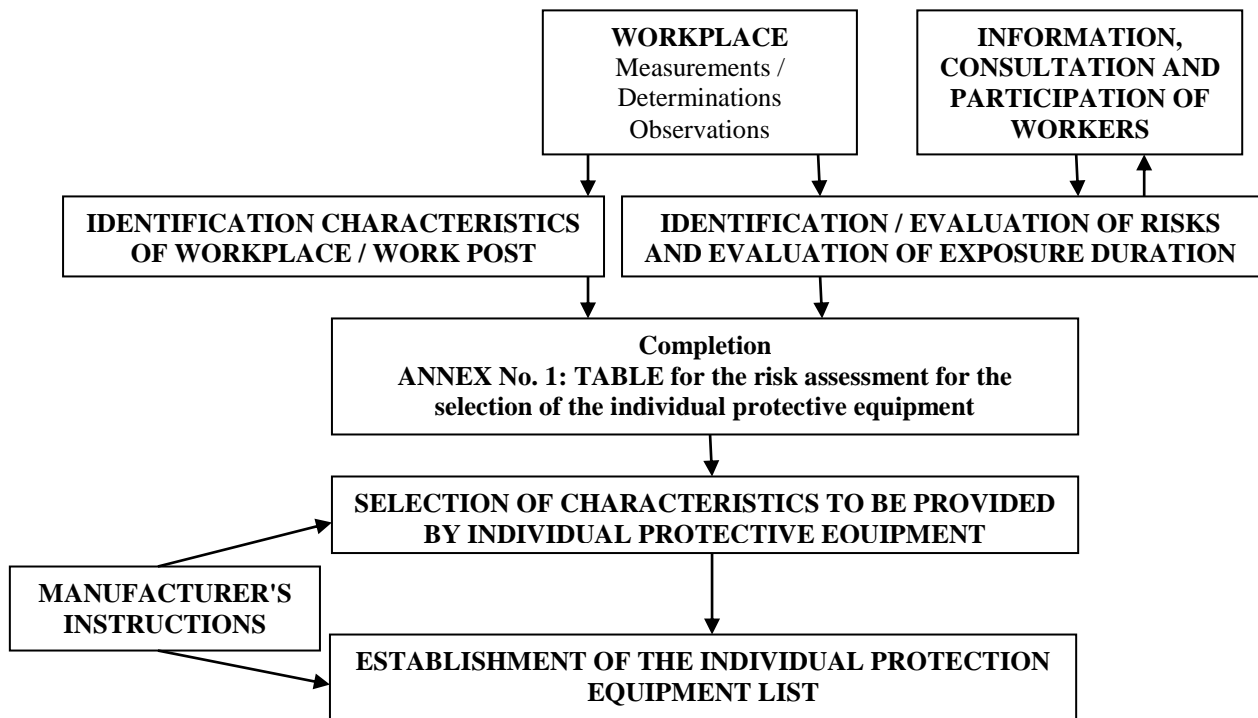


Fig. 1. Risk assessment process for the selection of personal protective equipment

The calculation of the normal use time may be influenced by the nature of the activity carried out or the properties of the individual protective equipment starting from disposable, up to eight hours / a work shift in certain environments up to four or five years in the case of helmets. With the exception of single-use protective equipment, the other categories may be normalized by a calculation that calls into question the time (storage or maximum permissible use), a value component influenced by the risk factors / hazards arising in the performance of the task and which can be eliminated / diminished by PPE and can lead to a degree of wear plus values related to maintenance tracking (proper washing and decontamination), handling (training of workers and proper use) and adequate storage (conditions to be met comply with the manufacturer's instructions). As far as the verification of the equipment before use is concerned, it requires at least visual inspection, but for some types the use, even if it is normalized, will be conditioned by marking or the existence of periodic tests carried out in specialized laboratories.

### 3. Conclusions

In view of the large number of legal provisions, the degree of subjectivity in identifying and assessing risks, and the lack of proposals for measures for all identified risk factors, the cumulative work carried out by some workers, the costs of carrying out the noxious determinations, and at least the estimation of the exposure duration plus the lack of awareness, consultation and participation of workers in the process of selecting personal protective equipment may lead to unjustified costs and the inappropriate use of PPE.

The selection of individual protective equipment is a difficult, complex, observational, measurement and estimation process that, along with the technical knowledge of occupational safety and health workers, should be supplemented by information provided by workers. (Babuț et al., 2018; Mihai-Adrian et al., 2017)

Once the assortment has been selected, choosing a particular product from the manufacturers and distributors' offer should not principally introduce the financial connotations but compliance with product standards, compliance with the marketing requirements and the maximum allowable wearing time calculated by the manufacturer before the loss the quality of protection of that equipment, which will allow for the acquisition of the purchase costs in time of use.

Regulation no. 425 of 9 March 2016, the instructions to be provided by the manufacturer "with PPE", obligations taken over by distributors help the employers, those who make the selection and acquisition of PPE and the help of those who contribute to proper cleaning, fact which will lead to keeping the protection features longer.

Specifying types and test intervals will allow you to create graphs for their execution, scheduling, and cost breakdowns.

Placing on the market on 21 April 2019 only of individual protective equipment that fully complies with the requirements of Regulation no. 425 of 9 March 2016 will benefit to increase the security level of workers using PPE and, through the content of the manufacturer's instructions, will make a real contribution to the selection, acquisition, use, verification, and proper maintenance of PPE.



## References

- Antonov, A., Hențulescu, V., Poruschi, F., Dobrescu, E., Crăciun, N., *Workplace Safety and Health Guide on the use of PPE*, INCDDPM Bucharest, (2013).
- Babut, G. B., Moraru, R. I., Occupational risk assessment: imperatives for process improvement. *Quality - Access to Success*, Vol. 19, Issue 166, pp. 133 – 144, (2018).
- Darabont, D.-C., Moraru, R. I., Antonov, A. E., Bejinariu, C. Managing new and emerging risks in the context of ISO 45001 standard, *Quality - Access to Success*, Vol. 18, pp. 11–14, (2017).
- Mihai-Adrian, B.-S., Iulian, I., Constantin, B., Costin, D. D., Alexandru, L., Marian, C. A., Costica, B. Improving safety in the workplace using checklists legal requirements. *Quality - Access to Success*, Vol. 18, pp. 31–34 (2017).

## Legal regulations and laws

- Decision no. 1048 of 9 August 2006 on minimum safety and health requirements for the use by workers of personal protective equipment at the workplace.
- Decision no. 355 of 11 April 2007 on the health surveillance of workers.
- Law nr. 319 from 14<sup>th</sup> of July 2006 on safety and health at work enforced by the Decree nr. 956 from 13th of July 2006, Published in The Official Monitor number 646 since 26th of July 2006.
- Norms from 11th of October 2006 to apply the Law's of safety and health at workplace forecasts nr. 319/2006 approved by The Decision nr. 1425 from 11th of October 2006, Published in The Official Monitor number 882 since 30th of October 2006.
- Regulation no. 425 of 9 March 2016 on personal protective equipment and repealing Council Directive 89/686 / EEC.
- Working Code of 24 January 2003 (Law No 53 of 24 January 2003) - REPUBLIC.

## Occupational safety and health audit between theory, legal requirements and practice

Baciu Constantin<sup>a</sup>, Bejinariu Costică<sup>a</sup>, Darabont Doru Costin<sup>b</sup>, Corăbieru Anișoara<sup>a</sup>,  
Bernevig-Sava Mihai-Adrian<sup>a,\*</sup>

<sup>a</sup> "Gheorghe Asachi" Technical University of Iasi, D. Mangeron Blv., no. 67, 700050, Iasi, Romania

<sup>b</sup> INCDPM "Alexandru Darabont", 35 A, Ghencea Blv., Sector 6, 061692, Bucharest, Romania

---

### Abstract

Even if at first instance the audit was considered to be the financial field, the need for checks, examinations, the collection of data or information to allow "an opinion on the degree of correspondence between the observed and some predetermined criteria" became necessary various areas including health and safety at work. The opinion expressed in the examination of the information gathered, at least in the field of safety and health at work, can be reported to a certain standard starting from the "minimum safety and health requirements" contained in the legal provisions in force and applicable to a work system.

*Keywords:* occupational safety and health, audit, health and safety, minimum safety and health requirements.

---

### 1. Introduction

In most of the papers in the literature, the audit focuses on legal requirements in a particular field and / or where, depending on some considerations that are mainly relevant to the requirements of a market segment or size of that unit, it may have implemented a system to manage, it is an essential process in increasing the level of health and safety at work.

Considering the complexity of the audit process, we will use the term "occupational safety and health audit" rather than the "audit for safety and health at work" to allow the collection and examination of data and information from a wider spectrum, legislative areas.

### 2. Occupational safety and health audit – theory and legal requirements

Occupational safety and health at international level is regarded as an activity, an area that includes education, training, with the main purpose of identifying dangerous conditions, materials and practices at work, and helping employers and workers to eliminate or reduce risks associated.

Health and safety at workplace as a term, in practice, tends to simplify and reduce the complexity of this area. This often leads to a limited view of the audited work system and implicitly to the reduction of legal regulations applicable within that unit, the lack of specific documents.

The nature of the "systematic process" in occupational safety and health audit implies that its activity is systematic, independent and documented. (Baciu et al., 2006; Băbuț et al., 2014) Thus, depending on the subject of the audit, it should take the audit of compliance with the requirements of the legislation in the field of occupational safety and health, plus the related legislation, which allows the realization of the functional framework of the work system as follows:

- legislation on the functioning and the way of setting up of commercial companies;
- work legislation;
- aspect of occupational medicine;
- legislation in the field of emergency situations;

---

\* Corresponding author. Tel.: +4-0755-252-527.

E-mail address: mihaibernevig@tuiasi.ro

- legislation on transport and traffic safety;
- specific legislation in fields of activity that lead us to the need for obtaining approvals, authorizations in respect of work equipment and professions / occupations for which there are special requirements for the organization of professional training (National Regulatory Authority for Energy, State Inspection for Boiler Control, Pressure Vessels and Lifting Installations, etc.).

Having in the foreground only one of the legal provisions applicable to all work places, respectively the provisions of the Methodological Norms of October 11, 2006, implementing the provisions of the Law on safety and health at work no. 319/2006 approved by the Decision 1425/2006 which at art. 15, paragraph 1, point 2, after the elaboration and fulfilment, "monitoring and updating of the prevention and protection plan" and in item 28 "monitoring the update of the warning plan, the protection and prevention plan and the evacuation plan" , together with paragraph 3, which requires a review of the risk assessment on safety and health at work:

- "whenever changes or changes occur in technology, work equipment, chemical substances or preparations used and work / workplace arrangements;
- "to discover the omission of risks or the emergence of new risks; "

If we remove from the context "monitoring", "tracking the update", "reviewing" "whenever changes or changes occur" or "finding out omission" together with at least two components of the table in Annex no. 7 The Methodological Norms of October 11, 2006, implementing the provisions of the Law on Safety and Health at Work no. 319/2006 which represents the Prevention and Protection Plan, respectively the action columns for the purpose of achieving the measure and the deadline, can lead us to the necessity but not the obligation to carry out an audit program in the field of safety and health at work. In audits planned after deadlines and targeted for clear goals, it will be possible to obtain results, evidence that can lead to the identification of opportunities to achieve improvements in the applicable health and safety aspects at work, all without having that place to implement a management system

If we remove from the context "monitoring", "tracking the update", "reviewing" or "finding out omission" together with at least two components of the table in Annex no. 7 The Methodological Norms of October 11, 2006, implementing the provisions of the Law on Safety and Health at Work no. 319/2006 which represents the Prevention and Protection Plan, respectively the action columns for the purpose of achieving the measure and the deadline, may lead to the necessity but not the obligation to carry out an audit program in the field of safety and health at work. In audits planned after deadlines and targets for clear targets, it will be possible to obtain results, evidence that can lead to the identification of opportunities to achieve improvements in applicable health and safety aspects at work, all without having that place to implement management system.

In the context of a small organizational and functional framework of a small or medium-sized unit but also applicable to large or very large units without fully meeting the requirements of an audit method compared to established methods (Workwell, Alberta, CHASE etc.) the method of auditing conformity with the provisions of the legislation in the field of safety and health at work based on the method of assessing the level of work safety elaborated by INCDPM Bucharest presents the most elements for identifying dangerous conditions, materials and practices for workers at work. The revised and improved version of this method allows for an effective, flexible and adaptable analysis of how general and specific legal requirements are known and applied within a work system. (Băbuț et al., 2018; Bejinariu et al., 2017a, b) This aspect permits to manage in a properly way the new risks, the organizations should adopt new approaches to continually improve their OHS performance.

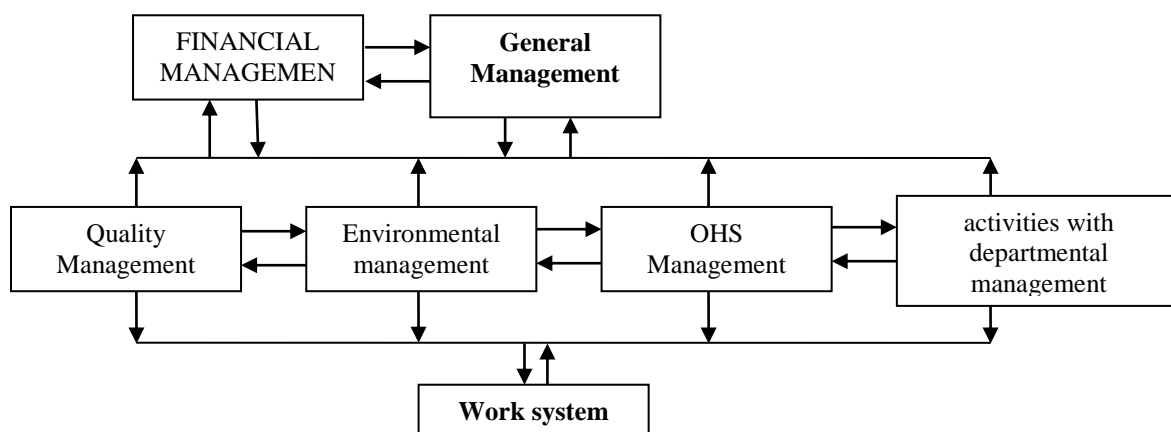


Fig. 1. Management Interdependence

Considering that management is in various forms in any activity carried out, depending on the size of the unit, both territorial, functional and as a number of activities and workers, it may have distinctly organized various types of management contained in the overall management of the unit / management being directly involved in meeting legal requirements and managing resources in relation to market requirements, the interdependence of the types is influenced by their need in relation to the size of the activity, the financial management and approved at the general management level, a process described briefly in Fig. 1.

### 3. Occupational safety and health audit – practice

Given that in practice the market only has an indirect role to influence the evolution of an enterprise and the culture of safety and health at work is still in the process it can be distinguished, in most cases, that regardless of the organization of the activity and implicitly of the management / the management of the implementation of a management system, except for the implementation of ISO 45001, does not lead to convergence of information, documents and organization in the field of occupational safety and health. This only makes the OHS management more difficult by duplicating staff and documents at the level of the work system which will lead to a general perception of distorted perceptions, mainly purely financial considerations. (Darabont et al., 1997, Darabont et al., 2001, Darabont et al., 2017)

The conditioning of the implementation of a management system in the procurement process does not guarantee its functionality due to the small size of some units and for the case of large or very large units that have opted for the implementation of a management system rarely make direct connection between the elements of the work system with aspects of occupational safety and health and managerial interdependence as a whole. (Mihai-Adrian et al., 2017)

Audit in the field of occupational safety and health, due to its complexity and diversity, will clearly be distinguished in two distinct categories, namely:

- audit of compliance with the requirements of the relevant legislation and requirements in related fields applicable at the level of a work system;
- audit of the occupational safety and health system. (Moraru et al., 2002; Moraru et al., 2014)

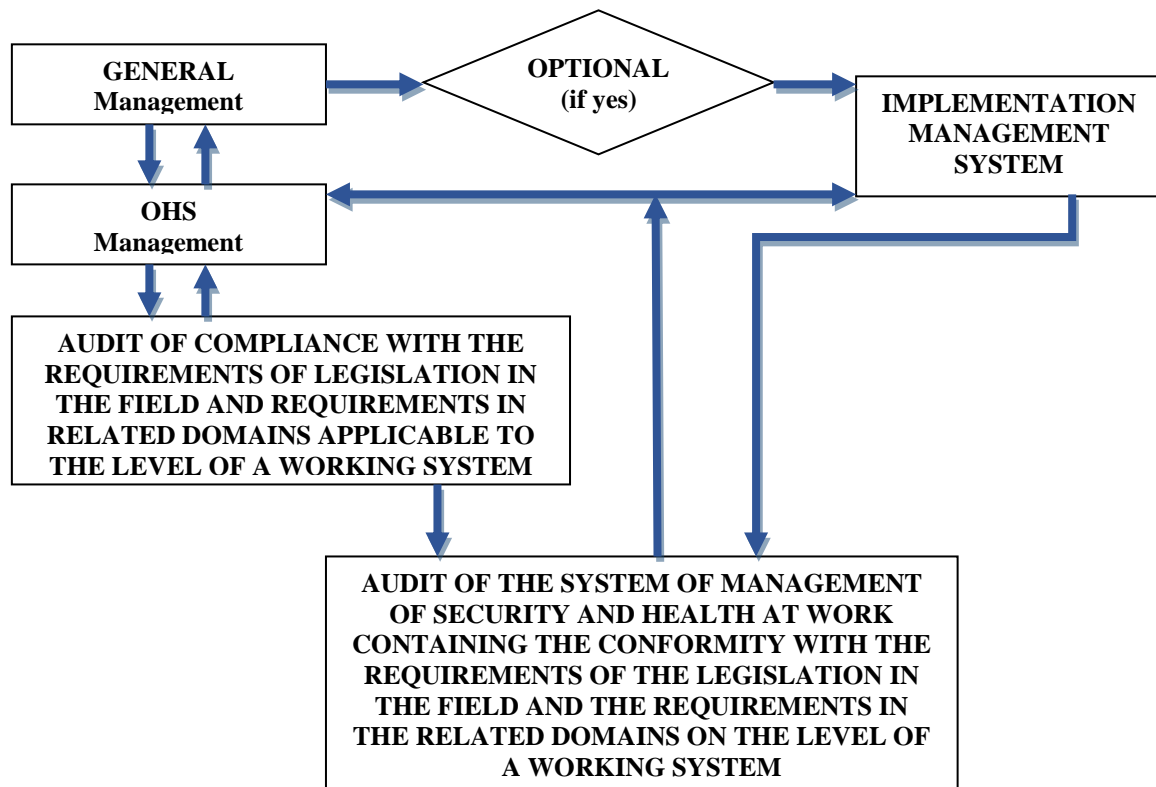


Fig. 2. Audit in the field of health and safety at work

The fact that literature puts them in distinct categories does not alter the practical reality of interdependence, conditional and complementary, which directly competes with the observance of legal requirements in an organized, planned, for realization and verification framework. The schematic presentation of the audit in the field of occupational safety and health is in Fig. 2, being part of the OHS management at the level of the work system, which in turn is a component integrated into the general management, and enter into the system of managerial interdependence in the case of larger units.

### 4. Conclusions

Regardless of the size of the work system and management activity, fulfilling legally binding requirements and applying them as accurately as possible can make a significant contribution to the development of a culture of occupational safety and health. Awareness of the complexity of the activity carried out and its organization in accordance with the legal requirements contained in the legislation in various fields is a quality of the specialized personnel, which can contribute, together with the education system at all stages and forms, to the awareness of the potential danger that is known before starting an activity and avoiding the occurrence of dangers.

Occupational safety and health audit allows for an x-ray on a work system to make the outcome obvious and to contribute to improving the safety and health of workers. Making it happen by people who understand the legal system and how to apply it to a work system can bring real benefits by streamlining the OHS management, reducing risk by proposing measures with real applicability, reducing spending and increasing credibility within the workforce enterprise.

In the context of what has been said, it can be said that the results of an audit of safety and health at work are all the more valuable as the practical and applicative impact on the audited work system will bring improvements.

## References

- Baciu, C., Darabont, D., Solonariu, L., Audit of Health and Safety at Work I – Training, (2006)
- Băbuț, G.B., Moraru, R.I., Audit in the field of Occupational Safety and Health: A Guide to Practical Applications and Projects, Publishing House Universitas, Petroșani, (2014)
- Băbuț, G. B., Moraru, R. I., Occupational risk assessment: imperatives for process improvement. *Quality - Access to Success*, Vol. 19, Issue 166, pp. 133 – 144, (2018).
- Bejinariu, C., Darabont, D.-C., Baciu, E.-R., Georgescu, I.-S., Bernevig-Sava, M.-A., Baciu, C., Considerations on Applying the Method for Assessing the Level of Safety at Work. *Sustainability*, Vol. 9, pp. 1263, (2017)a.
- Bejinariu, C., Darabont, D. C., Baciu, E. R., Ionita, I., Sava, M. A. B., Baciu, C. Considerations on the Method for Self Assessment of Safety at Work, *Environ. Eng. Manag. J.* Vol. 16, pp. 1395 –1400, (2017)b.
- Darabont, D.-C., Moraru, R. I., Antonov, A. E., Bejinariu, C. Managing new and emerging risks in the context of ISO 45001 standard, *Quality - Access to Success*, Vol. 18, pp. 11–14, (2017).
- Darabont, D., Occupational health and safety management, conformity assessment guide to legal requirements, AGIR Publishing House, Bucharest, Romania, (2010)
- Darabont, Al., et al., Guide for assessing the safety, the Scientific Research Institute for Labour Protection, Bucharest, Romania, (1997)
- Darabont, Al., Pece, Șt., Dăscălescu, A., Occupational health and safety management (vol. I and II), AGIR Publishing House, Bucharest, Romania, (2001)
- Mihai-Adrian, B.-S., Iulian, I., Constantin, B., Costin, D. D., Alexandru, L., Marian, C. A., Costica, B. Improving safety in the workplace using checklists legal requirements. *Quality - Access to Success*, Vol. 18, pp. 31–34 (2017).
- Moraru, R.I, Băbuț, G.B., Matei, I., Occupational risk assessment guide, Focus Publishing House, Petroșani, Romania, (2002)
- Moraru R.I., Băbuț G.B., Cioca L.I., Rationale and criteria development for risk assessment tool selection in work environments, *Environmental Engineering and Management Journal*, 13, 1371-1376, (2014)

## Legal regulations and laws

- Law nr. 319 from 14<sup>th</sup> of July 2006 on safety and health at work eforced by the Decree nr. 956 from 13th of July 2006, Published in The Official Monitor number 646 since 26th of July 2006.
- Norms from 11th of October 2006 to apply the Law's of safety and health at workplace forecasts nr. 319/2006 aproved by The Decision nr. 1425 from 11th of October 2006, Published in The Offical Monitor number 882 since 30th of October 2006.

## Transformation of the geodynamic hazard manifestation forms in mining areas

Batugin A.S.<sup>a</sup>, Kolikov K.S.<sup>a</sup>, Ivannikov A.A.<sup>a\*</sup>

<sup>a</sup>MISiS, Russia, 119049, Moscow, Leninsky Prospect, 4

---

### Abstract

The problems of geodynamic safety assurance in mining are common for many countries with developed mining industries. Considerable results have been achieved in Russia in solving rockburst problem, yet in the last decades this problem is transforming into man-triggered seismicity problem. Induced earthquakes in areas where mines had been flooded, seismic activity in previously safe regions, re-activation of tectonic faults, violent man-triggered earthquakes in open pit operations have been registered. As a matter of fact, a number of mining regions with technogenic seismicity have emerged in Russia, where geodynamic events not only cause financial or physical damage, but also negatively affect the environment, bring about social tension, impose additional risk for hazardous industrial operations.

Manifestation of seismic events at the sites of closed mines, seismic activation of geodynamically hazardous zones including those located at a significant distance from mining activities, anthropogenic earthquake in the vicinity of a large coal pit - all of the above in Kuzbass - are considered in this paper.

In this context the centrepiece in geodynamic safety assurance and prevention of geodynamic hazards is geodynamic zoning. Advanced geodynamic monitoring of the rock massif and the earth's surface is required when mining in geodynamically unsafe areas or planning for the re-use of mine workings.

*Keywords:* rockburst, technogenic seismicity, geodynamic safety, geodynamically unsafe areas, social and environmental damage

---

### 1. Introduction

Geodynamic risk in mining is a genuine concern for many world's mining regions [Kozyrev and Lovchikov, 2013; Han et al., 2016; Jiang et al., 2014; Orlecka-Sikora et al., 2014; Zhirov et al., 2015; Malovichko et al., 2012; Marot et al., 2014]. Earlier geodynamic factor imposed hazard on mining sector only, yet in the last decades geodynamic events cause physical, environmental and social damage. Major rockbursts are manifested as man-triggered earthquakes that impose diverse effects on the environment.

An important feature of such geodynamic events is their suddenness, unexpectedness, and the fact that they create a new seismic background [Lomakin and Kholevin, 2002; Emanov et al., 2014]. Another distinctive feature is that epicentres of geodynamic events are located beyond the boundaries of the mining lease, and this rules out the possibility for the mine to exercise control over these areas for protective purposes.

First rockbursts in the mines of the USSR were recorded in 1950s in the Kizel coal basin. The origin and mechanism of these phenomena were understood by mid-1970s when control and precautionary measures were schemed out. As a consequence, the rock burst incidence in the mines of the USSR has drastically reduced by mid-1980s [Petukhov, 2004]. However, at approximately the same time heavy rock bursts began to occur that were referred to as tectonic rock bursts.

Tectonic rock bursts at the Russian mineral deposits caused quaking on the surface, shattering of buildings, they brought about surface subsidence, cracks, sunken streams, gross physical damage. On top of all this, considering that many deposits liable to rock-bumps are developed in heavily populated industrial areas, seismic threat of tectonic rock bursts for hazardous production facilities became evident. It can be stated therefore that a number of mining regions liable to induced seismicity have emerged in Russia. Such regions include Kemerovo Oblast with Kuzbass, the Urals, mining fields in Kola Peninsula, areas where potash salt is mined in Perm Oblast (Berezniki and Solikamsk cities). While other risks are a traditional threat for mines [Kaledina et al., 2016; Puchkov et al., 2015; Kachurin et al., 2017;

---

\* Corresponding author. Tel.: +7-903-757-1047.  
E-mail address: as-bat@mail.ru.

Morozov and Tatarinov, 2006; Rybak, 2014; Batugin et al., 2018; Nazarov et al., 2014], issues related to natural seismicity assessment [Balan et al., 2017; Kossobokov, 2013] remain unaddressed, and manifestations of geodynamic activity create new conditions in mining regions.

## 2. New forms of geodynamic hazard manifestation in mining areas (as illustrated by Kuzbass cases)

### 2.1. Technogenic earthquakes related to flooded mines.

Restructuring of coal mining sector was commenced in Russia in mid-1990s. A total of 200 unprofitable deep and surface mines has since been shut down.

Mine closure was performed either by flooding, or using dry and combined approaches. Where flood method was chosen mine pumping system was shut off and excavations were filled with water. In case of dry liquidation mine operations were stopped yet mine pumping system continued to operate. Combined method was preferred where water level in the abandoned mine had to be monitored to prevent potential water inrush to productive workings of neighbouring mines. Mass scale mine closure gave rise to new environmental risks in mining areas. Raising of water level in mines caused expulsion of water to the day surface and flooding of subsided terrain. Places were spotted where ground water was cropping out onto surface and/or discharging into surface water bodies. Part of the adverse environmental consequences was predicted by the federal environmental monitoring laboratories that were established in mining regions [Kharyonovskii et al., 2010]. Forecasts were made for changing geomechanical conditions triggered by mine closure [Fisun et al., 1997]. The question, however, if geodynamic phenomena may develop as consequent effect of mine flooding was left unattended by specialists.

Although initially no seismological monitoring was carried out in regions where mines were being shut down, the relation between mine flooding and seismicity can be traced by indirect indicators. Table 1 provides the dates mines were flooded in Kuzbass and dates of shallow-focus earthquakes. As can be seen from these data, there is a direct link between the beginning of mine flooding process and shallow-focus earthquakes that followed. Anzherskaya mine in Kuzbass, for example, was recovering a number of coal seams and by the date of closure it was over 700m deep. Mine flooding started in 1995, the average rate of water level raise was 10 m/month. By April 1997 water level in the mine raised by over 200 m. It was then that earthquakes occurred with epicenters located directly in the mine field. Thereafter geodynamic test range was established at the site of Anzherskaya mine to conduct field monitoring.

Indirect relation between mine flooding process and enhanced seismicity of the area could also be observed at the Kizel coal basin in the Urals. Flooding of mines there started in late 1980s. Since that time the burst of seismic activity in this region was registered after a lengthy (30 years) off-seismic period, according to Lomakin V.S. [Lomakin and Kholevin, 2002].

Table 1. Seismicity in Kuzbass vs. Mine Flooding Process

Kuzbass Region	Date of Earthquake	Earthquake Magnitude
Anzhersky	25.10.97	M=2.3
Anzhersky	30.10.97	M=2.3
Prokopyev-Kisselyovsky	1995	5-6 score, M=4.6

As to mechanism of earthquakes that happened after mine flooding, authors from different countries believe it is similar to that observed in large dam lake projects [Batugin and Klimanova, 2000; Srinivasan, 2000; Goldbach, 2009]. One of key mechanisms that triggers technogenic earthquakes when filling dam lakes is considered to be due to rise of fluid pressure in tectonic fault planes [Gupta and Rastogi, 1976]. Normal compression of fault limbs  $\sigma'_n$  is reduced by water pressure value  $p$ , while tangential shearing stresses  $\tau_n$  in the fault plane remain unchanged:

$$\sigma'_n = \sigma_n - p = \sigma, \quad (1)$$

$$\tau_n = \tau = \tau. \quad (2)$$

As normal compression is reduced, confining force in the fault plane also decreases. At some moment the force of shearing stresses becomes great enough to overcome confining force and it is then that rock movement along fault plane occurs and seismic energy is released.

After mining operations are completed the rock material in abandoned space remains less compact with micro fissures capable to transfer hydrostatic water pressure. Such rock mass is also weakened by major disjunctive dislocations, their fault planes intersected by mining operations. Therefore, this mechanism may come into action following mine flooding, especially since quite often flood water level in abandoned mines is higher than that in dam lakes where earthquakes were registered.



## 2.2. Technogenic earthquakes in producing mine areas

In the vicinity of producing mines seismicity is observed with hypocentres located much deeper than the depth of mining operations. Similarly, seismic activity is triggered within rock mass areas far beyond the mine lease. The fact that seismic hypocentres are located at great depths and far away from mining operations is attributed to critical stress condition acquired by these areas due to mining activity and tectonic stress field [Petukhov, 2004].

Thus, technogenic seismicity around Polysayevo in Kuzbass were becoming more and more evident since 2006 in the vicinity of Oktyabrskaya and Polysayevskaya mine fields where coal mining was aggressive. In 2008-2009 a number of foreshock activation areas evolved. This was described in paper [Emanov et al., 2009]. Areas II, III, IV and V were related to mining operations, whereas areas I and VI were located beyond the boundaries of mining operations and had no connection to working excavations, see Fig 1. More than 25 years ago works on geodynamic zoning were completed in this part of Kuzbass. Modern crust blocks of various hierarchical ranks were identified and stress condition of the rock mass was assessed [Batugina and Petukhov, 1990]. According to data available for this region, there is a tectonic stress field with horizontally oriented axis of maximum compression, whereas boundaries of NW-trending blocks exhibit strike slip component.

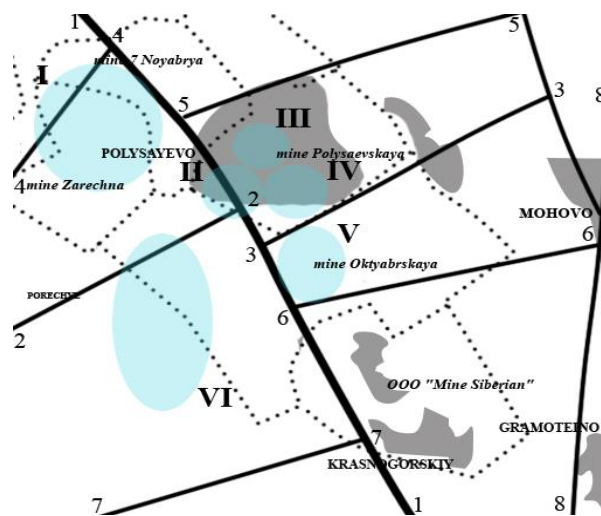


Fig. 1. Polysayevo district block outline with areas of seismic activity according to materials [Emanov et al., 2009; Batugina and Petukhov, 1990] (explanatory text).

Comparison between seismic activity areas and outline of modern block structure shows that seismically active zones II, IV, V are located next to boundaries of II rank blocks, particularly, in intersection node of II and III rank blocks boundaries. The seismically active area I is registered at III rank blocks boundary, where abandoned excavations of '7 November' and 'Komsomolets' mines are located. According to [Emanov et al., 2009] hypocentres of several seismic events are recorded at the depth of 2 to 3 km and were triggered by thrust faulting. Thrust faulting mechanism behind seismic events is the proof that it is modern stress field with horizontally oriented axis of maximum compression, that participates in seismic process, which is in line with geodynamic zoning materials.

## 2.3. Induced earthquakes in open mines

Heavy rockbursts and technogenic earthquakes were registered in recent decades in open mines of Russia and neighbouring territories [Kozyrev and Lovchikov, 2013; Emanov et al., 2014; Aitmatov, et al., 2004]. These events caused physical, social and environmental damage and were unexpected for specialists. Mechanism of these phenomena need to be studied, however there are some common features in tectono-physical nature of these events.

Tectonophysical research on the pattern of tectonic rock bursts in mines demonstrate that their hazard is linked to re-activation of major tectonic dislocations, optimally located in the rock mass relative to the axes of tectonic stress field [Batugin et al., 2016; van Aswegen, 2017]. Review of data obtained from geodynamic zoning of Kuzbass [Batugina and Petukhov, 2017] reveals that Bachat induced earthquake may be related to re-activation of major upthrow fault that undercut the pit at a great depth, see Fig 2. The depth of Bachat pit is approximately 300 m, its length being approximately 10 km and width 2 km. Mining operations include regular blasts with up to 350 t net explosive content.

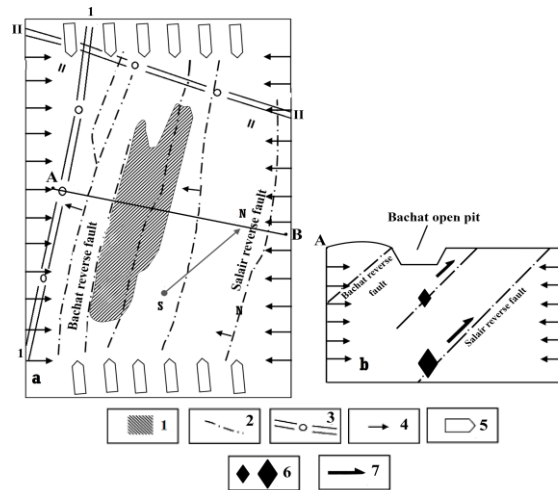


Fig. 2. Simplified tectono-physical layout of Bachat coal pit area: 1 – Bachat pit; 2 – tectonic dislocations; 3- second rank crust block boundaries; 4, 5 – direction of maximum compression for 2nd and 3d rank stress fields respectively; 6 – provisional hypocentres of aftershocks and the main shock; 7 – direction of thrust fault wall displacement brought about by earthquake

There is a series of major thrust faults in the vicinity of the Bachat pit (Tyrgansky, Bachatsky, Salairsky), dipping at 50-70 degrees towards SW. No detailed study has been ever made on the deeper strata of this part of Kuzbass, yet available regional geologic materials allow to suggest that upthrow faults extend to considerable depth and undercut the Bachatsky pit at the depth of several kilometres, see Fig 2-b. Direction of maximum compression in this part of Kuzbass is horizontal from SW to NE, i.e. approximately perpendicular to thrust faults trending.

Magnitude of Bachatsky earthquake in 2013 was  $M=6.1$ , whereas hypocentre was at the depth of 4 km. Mechanism of that event was thrust fault [Emanov, et al., 2014]. Drawing on the approach we stick to, it can be assumed that at the time of Bachat earthquake displacement might have occurred of the hanging wall of Salair or other major thrust fault under the pit optimally located in relation to direction of maximum compression, see Fig 2. Indeed, in the modern stress field the Salair fault behaves as classic thrust fault and may extend to the depth of several kilometres below the pit. During the earthquake a thrust fault occurred along the plane that by mode of occurrence concurs with the Salair thrust fault. In other words, during the earthquake and subsequent aftershocks major thrust faults got re-activated whereby their upthrown side was displaced in line with current stress field effect, see Fig 2.b.

### 3. Discussing the findings

Seismicity caused by flooding deep mines, activation of geodynamically risky areas outside mine boundaries, heavy rockbursts and technogenic earthquakes in the pits – all of these are fairly new phenomena not only for Russia but for other countries with mining industries. After shutting down and flooding mine excavations, seismicity was recorded at mine fields of Czech Republic, India, SAR, France [Marot et al., 2014; Batugin and Klimanova, 2000; Srinivasen et al., 2000]. This new risk has to be taken into account in mine construction and mine closure projects, especially in heavily populated industrial areas.

Induced earthquakes and heavy rockbursts outside mine takes or in abandoned areas of mine fields seem to be one of latent relationships between natural and technical systems. For example, a heavy rockburst at  $10^8 J$  occurred in 'Mine 15-15' at Severouralsky bauxite deposit on 20.02.1987 in the district abandoned 10 years earlier. Paper [Cernik, 1964] describes heavy rockburst on October 15th 1929 at the Tirolean ore mine (Austria) recorded at levels VIII and IX in the area where no mining operations had been performed for 55 to 60 years. On October 22nd 1930 heaviest rockburst occurred in a footwall gate at VII east level, near 1st South fault where nobody had worked for 42 years. On June 11th 1959, March 19th and 30th 1960, March 27th 1961 heavy rockbursts occurred in the ore mines of Kolar deposit. Epincentres of all these events were located far from the ore body [Taylor, 1963; Batugina and Petukhov, 1991; Xiang et al., 2018]. In the period between 1910 and 1960 rockbursts were recorded at Příbram ore mines (Czech Republic) at 20 km distance to the East, 10 km to the North and 10 km to the South of mining operations. These rock bursts were in the form of earthquakes and were registered by seismographs in Prague, Prugonitse and Kladno.

As rockburst control measures presumably shall be focused on the areas where mining operations are conducted and assumably it is excavations, openings, headings etc., where such measures shall be applied, onset of geodynamic risks outside mine property makes it difficult to implement such measures. Furthermore, a local mine net of seismic monitoring is not enough for reliable identification of seismic buildup zones. Seismic activation zones and epincentres of heavy rockburst located outside mine lease boundaries put at risk industrial operations and civil facilities on the surface. Consequently, new approaches need to be devised to assess geodynamic risks.

Cases when the depth of induced earthquake hypocentre was considerably more than that of mining operations indicate that the top layer of crust acquires critical stress. Due to mining operations and development of cavities/large gobs in shallow parts of such areas the stress-strain balance is continuously disturbed, hence stress redistribution may propagate much deeper than the depth of mining operations. Within this context the location of earthquake hypocentres at a great depth below mine or pit can be attributed to the fact that mining operations were actually performed in the regional critically stressed zone.

Furthermore, the proportion between the size of the tectonic rock burst origin  $r$  and the size of this event's background,  $R$ ,  $r/R=10-30$  [Batugin et al., 2016; Xiang et al., 2018] allows to assess the size of crust blocks involved in induced earthquake lead up. Taking the magnitude of the Bachat earthquake as  $M=6.1$ , the size of earthquake source  $r$  must be at least 10 km. Then the event's background size  $R$  would amount to 100 - 300 km, which is commensurable with geodynamically active crust blocks of the 2nd rank – Figure 2. In this case it may be assumed that interrelation between grand crust blocks creates critically stressed zones either inside the blocks or at their edges. Considering that geologic processes develop fairly slow, energy confined inside the limit state zones takes enough time to redistribute in the ground thus no conditions provoke rock shattering. When mining works advance at a high rate and/or in case of mass scale blasts in pits, load increment rate may exceed the rate of load release, thus conditions are created for onset of adverse geodynamic events. Taking into account that critically stressed areas built up due to geodynamic processes embrace primarily shallow strata of Earth's crust, monitoring shall be envisaged as part of mineral resources recovery and earth's surface exploitation.

#### 4. Conclusions

In addition to already known geodynamic phenomena (rockbursts and outbursts), new forms of geodynamic hazard manifestation have been observed in mining regions of Russia. No sufficient measures have yet been developed to address these risks. Technogenic seismicity brought about by mine flooding, seismic activation outside mine takes, heavy rockbursts and induced earthquakes in the pits cause not only physical, but also social and environmental damage, raise the probability of accident risk at hazardous industrial operations located in the region.

One of the reasons why in mining areas geodynamic hazard manifestation mode is changing may be interrelation between global tectonic processes and grand-scale engineering human activity. From this perspective, materials related to geodynamic zoning present interest for study. When mining in geodynamically risky zones, advanced geodynamic monitoring shall be established in mining areas and on the earth surface.

#### References

- Kozyrev, A.A., Lovchikov, A.V., Review of the strongest rockbursts and mining-induced earthquakes in Russia. *Journal of Mining Science*, Vol.49, No.4, pp. 572-575, (2013).
- Han, J., Zhang, H., Liang, B., Rong, H., Lan, T., Liu, Y., Ren, T., Influence of large syncline on in situ stress field: a case study of the Kaiping coalfield, China, *Rock Mech Rock Eng*, Vol.49, pp. 4423-4440, DOI: 10.1007/s00603-016-1039-4, (2016).
- Jiang, Y.-D., Pan, Y.-S., Jiang, F.-X., Dou, L.-M., Ju, Y. 2014. State of the art review on mechanism and prevention of coal bumps in China. *J. Meitan Xuebao/Journal of the China Coal Society*. Vol.39, No.2, pp. 205-213, (2014).
- Orlecka-Sikora, B., Cesca, S., Lasocki, S., Węjacz, P., Rudzinski, L., Seismogenesis of exceptional ground motion due to a sequence of mining induced tremors from Legnica-Głogów Copper District in Poland. *Geophysical Journal International*, Vol.198, No.1, pp. 40-54, (2014).
- Zhirov, D., Glaznev, V., Zhirova, A., *Proceedings of the 15th International Multidisciplinary Scientific GeoConference & EXPO (SGEM-2015), Albena (Bulgaria) 18-25 June 2015*. Vol.1, pp. 97-104, (2015).
- Malovichko, D., van Aswegen, G., Clark, R., Mechanism of large seismic events in platinum mines of the Bushveld Complex (South Africa). *The Journal of the S. African Inst. of Mining and Metallurgy*. Vol.112, pp. 419-429, (2012).
- Marot, M., Kinscher, J., Coccia, S., Contrucci, I., Klein, E., Bigarré, P. Mine induced seismicity: From a passive microseismic monitoring in complex near-field underground conditions to an open & accessible database. *5th EAGE Passive Seismic Workshop: From Wish List to To-Do List*, Lisbon; Portugal, 28 Sept.- 1 Oct. 2014, (2014).
- Lomakin, V. S., Kholevin, N. I., The position of tectonic rock bursts in the real seismicity of the Urals, *Geodynamic safety in the development of subsoil and the Earth's surface*. - Apatity: Publishing house KSC RAS, pp. 79-89, (2002).
- Emanov, A. F., Emanov, A.A., Fateev, A. F., Leskova, E. V., Mining-induced seismicity at open pit mines in Kuzbass (Bachatsky earthquake on June 18, 2013). *Journal of Mining Science*. Vol.50, No.2, pp. 224-228, (2014).
- Petukhov, I. M., *Rock Burst in Coal Mine*, Saint Petersburg, 237 p., (2004).
- Kaledina, N.O., Kobylkin, S.S., Kobylkin, A.S., The calculation method to ensure safe parameters of ventilation conditions of goaf in coal mines. *Eurasian Mining*, Vol.1, pp. 41-44, (2016).
- Puchkov, L.A., Kaledina, N.O., Kobylkin, S.S., Systemic approach to reducing methane explosion hazard in coal mines. *Eurasian Mining*, Vol.2, pp. 3-6, (2015).

- Kachurin, N.M., Stas, G.V., Korchagina, T.V., Zmeev, M.V., Geomechanical and aerogasodynamical consequences of underworking mining leases territories, of Eastern Donets basin mines, *Izvestiya TulGU. Sciences of Earth*, Vol.1, pp. 170-181, (2017).
- Morozov, V.N., Tatarinov, V.N., Tectonic processes development with time in the areas of HLW disposal from expert assessment to prognosis. *Int. Nuclear Energy science and Technology*, Vol.2, No.1/2, pp. 65-74, DOI: 10.1504/IJNEST. 2006. 010648, (2006).
- Rybak, J., Stress wave velocity tests in early-stage of concrete piles. *Proceedings of Concrete Solutions, 5th International Conference on Concrete Repair, Belfast, Northern Ireland, 1-3 September 2014* / eds. Michael Grantham, Boca Raton, CRC Press, Taylor & Francis Group. pp. 571-576, <http://dx.doi.org/10.1201/b17394-88>, (2014).
- Batugin, A., Odintsev, V.N., Yu, L., Kolikov, K., Khotchenkov, Ev. Displacement and mine seismicity processes during undermining of a tectonically active fault area at the Sinvay deposit. *Proceedings of the 18th Int. Multidisciplinary Scientific GeoConference (SGEM-2018), Albena (Bulgaria) 02-08 July 2018*, Vol.18, Issue 1.3, pp. 319-326, [doi.org/10.5593/sgem2018/1.3](http://doi.org/10.5593/sgem2018/1.3), (2018).
- Nazarov, L.A., Nazarova, L.A., Usol'tseva, O.M., Kuchai, O.A., Estimation of state and properties of various-scale geomechanical objects using solutions of inverse problems. *Journal of Mining Science*, Vol.50, No.5, (2014).
- Balan, S.F., Apostol, B.F., Ionescu, C., Brief Overview of Using Nonlinear Seismology in Analysis of the Soil Deposits Effects on Structure Location. *IOP Conference Series: Earth and Environmental Science* Vol.95, No.3, Article No. 0320133<sup>rd</sup> World Multidisciplinary Earth Sciences Symposium, WMESS 2017, 11-15 September 2017, (2017).
- Kossobokov, V. G., Earthquake prediction: 20 years of global experiment. *Natural Hazards*, Vol. 69, No.2, pp. 1155-1177, (2013).
- Kharyonovskii, A.A., Vaseva V.N., Kaplunov V.Yu. et al., *Environmental monitoring in the liquidation of mines and open pits* /general ed. Krasavin A.P., Navitniy, F.V., Kaplunov Yu.V. - Perm, 315 p., (2010).
- Fisun, A. P., Yakovlev, D. V., Zemisev, V. N., Yagunov, A. S., Geomechanical problems in the liquidation of mines in Russia, *Problems of geodynamic safety*. II Int. Workshop June 24-27, 1997 St. Petersburg, Russia pp. 50-55, (1997).
- Batugin, A. S., Klimanova, V. G. Assessment of the influence of the depth of flooding of the liquidated mines on the increase of the geodynamic hazard. *Deformation and destruction of materials with defects and dynamic phenomena in workings*. Simferopol, pp. 26-27, (2000).
- Srinivasen, C., Benady, S., Sivakumaz, C. Fluid Seismicity in Kolar Mining Region, *Proc of Workshop / Dam Safety, including Instrumentation of Dams*. Thiruvananthapuram, (2000).
- Goldbach, O.D. Seismic risks posed by mine flooding, *Hard rock safe safety conference*. Pretoria, pp. 149-174, (2009).
- Gupta, H.K., Rastogi B.K. *Dams and Earthquakes*. Elsevier, (1976).
- Emanov, A.F., Emanov, A.A., Leskova, E.V., Fateev A.F., Semin A.Yu., Seismic activation at coal mining in Kuzbass, *Fiz. mezomekh*, Vol.12, No.1, pp. 37-43, (2009).
- Batugina, I.M., Petukhov, I.M. *Geodynamic zoning of mineral deposits for planning and exploitation of mines*. Oxford & IBH Publishing Co. Pvt. Ltd. New Delhi. 159 p., (1990).
- Aitmatov, I.T., Kozhogulov, K.Ch., Nikolskaya, O.V., Geomechanical problems of development of upland deposits in the open-pit method in the mountain-folded areas, *Scientific and technical support of mining*. Vol.68, Part 1. Almaty, (2004).
- Batugin, A. S., Batugina, I. M., Lan, T. Tectonophysical model of fault tectonic rock burst with wing sliding. *Journal of Liaoning Technical University. Natural Science*, Vol.35, No6, pp. 561-565. DOI:10.11956/j\_issn. 1008-0562.2016.06.001, (2016).
- van Aswegen, G., Seismic sources and rockburst damage in South Africa and Chile. *Proceedings of the Ninth International Symposium on Rockbursts and Seismicity in Mines*, Santiago Chile, on 15-17 of Nov., pp.72-86, (2017).
- Černík, B., Statistical analysis of rock bursts over the period 1910-1960. *Horske Tlaky a Mech. Pohori*. pp. 284-295. Discuss. 367-385, Praha, (1964).
- Taylor, J.T.M. 1963 Research on ground control and rock bursts on the Kolar Gold Field, India. *Bull. Inst. Mining and Metallurgy*, Vol. 675, Trans., 1962-1963, Vol.72, No.5, pp. 317-338, (1963).
- Krishnamurthy, R., Investigations of problem of ground control and rockburst in the Kolar gold field. *J. Inst. Engr. Min. and Metall. Div.*, Vol.49, No.11, pp. 98-103, (1969).
- Batugina, I. M., Petukhov, I. M. *Bibliography of Rock Bursts*. Balkema, Rotterdam. 1991.
- P. Xiang, P., Ji, H.-G., Cai, M.-F., Zhang Y.-Z., *Rock and Soil Mech*. Vol. 39, No.2, pp. 457-466 (2018).

## Operating environment in Augmented Reality maintenance applications

Florina Luminita Besnea<sup>a\*</sup>, Stefan-Irinel Cismaru<sup>a</sup>, Nicu-George Bizdoaca<sup>a</sup>

<sup>a</sup> *Mechatronics and Robotics Department, Faculty of Control, Computers and Electronics, University of Craiova, Craiova 200440, Romania*

---

### Abstract

The year 2018 brings new challenges to the use of current technologies. Since very old times the human kind craved upon reaching the furthest goals, usually those it only dreamed of. To be able to accomplish, the human invented and implemented ways to bring him closer to his ultimate goal, namely, knowledge. Augmented Reality (AR) is the mean by which an idea, a concept or even a thought can be translated into a more interactive manner for the user. This paper brings to the forefront the use of Augmented Reality in an area where the barrier between material world and imagination is overcome, so a multitude of applications can be developed. The range of applications can begin by simulating simple scenarios for learning purposes to an immersive and complex virtual environment which will educate users to be able to react in extreme or dangerous situations. Conclusions available in the end of the paper will uncover the perspectives offered by introducing the AR as an operating environment in maintenance applications.

*Keywords:* Augmented Reality; environment; application; technology; maintenance.

---

### 1. Introduction

Although the augmented reality is not a relatively recent discovery, it has only recently grown and made itself remarkable throughout the world wide within a rather short time.

Having an early quite modest stage because device processing power was still premature and could not provide means for the full performance of the Augmented Reality, with the development of technology and mobile devices, this kind of reality has come to the hands of the ordinary user getting him used to what would come next, namely the development of a new type of reality.

One of the first applications which used this concept and made itself known was the scanning of QR barcodes. With a smartphone's camera, such code can be scanned and the information contained can be decoded. Of course, the performance of augmented reality is not just about the ability to get information from QR codes but can be extended to introducing 3D objects in the scene with the help of a graphic engine. Objects can be either static or dynamic, which means that interaction with them will allow manipulation in a convenient way for the user.

At a first look, AR seems to be a fictional area but it has become possible and accessible to the general public with the evolution of smartphones and gadgets capable of delivering such technology. AR can show its true contribution to areas that require a high level of complexity, reduced accessibility in the event of a large geographic spread of equipment to be maintained, difficult know-how exchange between experts and technicians and high costs of intervention for maintenance.

As with the word *“only sky is the limit”* the development of applications that will use this concept is limited only by the imagination of the developer. This paper aims to develop an application that will offer support to the personnel responsible of activities in maintenance applications.

### 2. Concept

Paul Milgram defines Mixed Reality (MR) as an environment in which the real world mixes with the virtual one and the result is displayed in one form, MR being the border between the two. Although MR offers both reality and Virtuality Augmentation (VA), the paper brings to the forefront the use of Augmented Reality.

Augmented Reality is part of Mixed Reality (MR) (Fig.1) and stands as a new concept that combines both software and hardware technologies which intend to improve the work environment and the workflow resulting in an enhanced labour quality. The idea of AR implies the use of optical devices assisted by the processing power of electronic ones to allow the overlay of 3D or 2d graphic elements over real objects. The result obtained through implementing this concept will be an improved environment providing more information and functionalities, which will allow a more precise interaction with it.

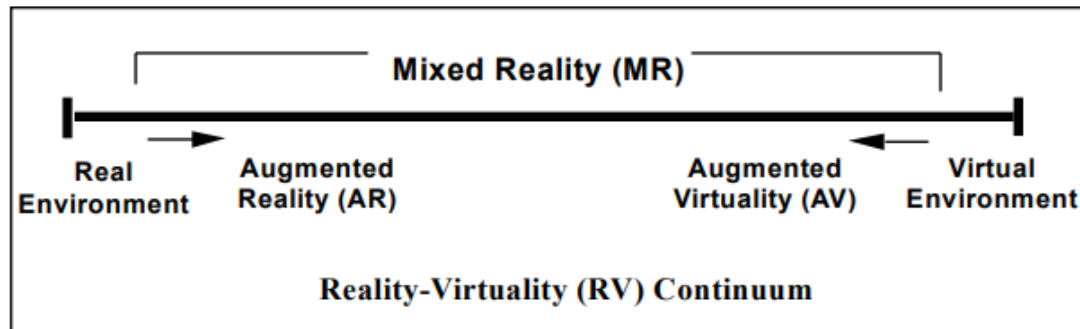


Fig. 1 RV Continuum

In fact, the AR is a live physical sight in which graphical elements developed on the computer are overlapped on real-world elements producing the semi-immersion of the user and stimulating his senses causing him to acquire new skills and support him in his activities.

### 3. Application

In developing such an application, key elements are needed to have a guaranteed success and to achieve the targeted purpose. Although the number and nature of the elements may vary from one application to another, their identification must be done correctly in order to have a final product with a great impact and increased utility.

Analysing the process which shall be supported by such an application must take place first and foremost because the data obtained can determine the type of objects to be designed and the type of interaction that will take place between user and application. Also, the analysis should consider the experts' opinion and the challenges they have faced over time. Not only the process analysis needs to be done in this manner, but also the development of the application. This must be done in close contact with technical process representatives who can provide a clear and accurate diagnosis over support information which shall be provided to the targeted personnel that will make use of the application.

This paper focuses mainly on the development of a maintenance application for the industry and also for the equipment that implies special attention and meticulous care, with the possibility of customizing according to the process needs and field of activity.

One way to develop an application which will deliver an augmented reality is using ArCore platform, the official and supported platform offered by Google. This platform targets Android compatible devices and will make use of its hardware for interpreting and understanding the environment. When using this library, every motion of the device is recorded and based on the input data coming from the sensors, the application creates a context similar to the real world but which allows alteration. At this point the basic setup is done and the next stage of development implies addition of new virtual elements in the scene.

For an experience rich in performance and high quality graphics ArCore can work with two compatible and powerful graphic engines, Unreal Engine and Unity 3D.

With the help of such an application, two major aspects are fulfilled, namely tele-maintenance and training of the designated personnel. By means of tele-maintenance, the information exchange takes place much faster and easier and the tasks are carried out more efficiently which in the end increases productivity. Also for productivity purposes, the application provides unconditional support to the service personnel training the with the correct skills necessary for the maintenance tasks.



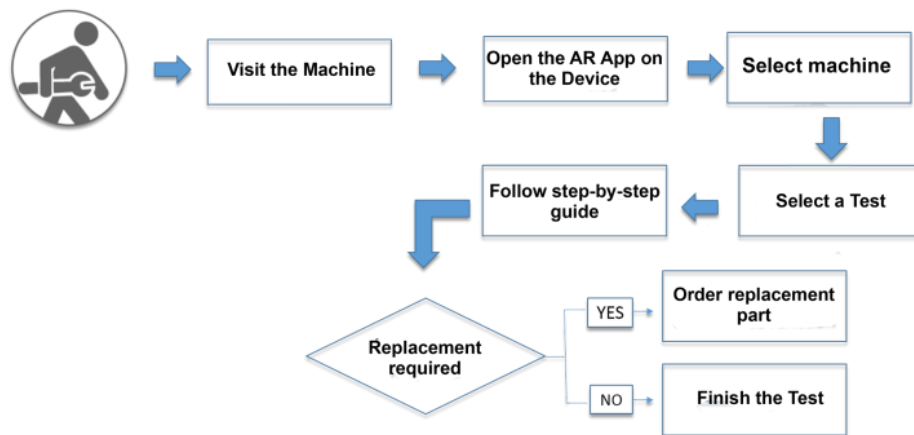


Fig.2 AR application workflow

The application aims to support the user by presenting a predefined interactive scene using a device capable of rendering augmented reality. The interactive scene presents itself as a graphical step-by-step guide for operating and manipulating a particular component in order to perform a maintenance operation, thus managing to provide the appropriate support (Fig.3).



Fig.3 AR application layout

#### 4. Conclusion

This paper presents the development and the perspectives offered by an operating environment in Augmented Reality maintenance Applications that can be used by less experienced technicians or users in different situations that typically require specialized expertise in maintenance problem solving.

The perspectives offered by developing such an application comprises and is not limited to:

- A mixed reality and semi-immersive experience
- Information available at a click away
- Training of the designated personnel in solving technical problems
- solving situations and maintenance problems in a short time, without any other cost / cost reduction
- Improves customer satisfaction - assures the assistance of any type of user (technical and non-technical)
- reproduces scenarios according to the specifics of the company or the work environment
- Ensure a higher level of knowledge transfer (know-how)
- Reduces errors and periods of inactivity in complex operations
- Provides accurate maintenance in a short time

Thus, the Augmented Reality technology incorporates a portable device with just one click away for any maintenance work required for a company's specificity.

## **Acknowledgements**

This research was supported by UEFISCDI - PN III- Bridge Grant - Partnership Ford Romania - University of Craiova to transfer, implementation and adaptation of Eco-technologies to model Ford EcoSport production at Craiova - 92BG/01/10/2016 - PN-III-P2-2.1-BG-2016-0123, Intelligent and Distributed Management of 3 Integrated Autonomous Systems Integrated into Emerging Technologies for Personal Medical Assistance and Providing Flexible Precision Production Lines (CIDSACTEH) - UEFISCDI - PN-III-P1-1.2-PCCDI-2017-0290 - 78PCCDI/2018 and grant Applied Research Science Infrastructure (INCESA) – 13845 SMIS – CSNR code - 256/28.09.2010 - ANCS, Programs POSCCE - A.2. - O. 2.2.1. – 2009.

## **References**

- Fite-Georgel, P., Is there a reality in industrial augmented reality ?, in '2011 10th IEEE International Symposium on Mixed and Augmented Reality', ISMAR '11, IEEE Computer Society, Washington, DC, USA, pp. 201–210, (2011)
- Friedrich, W., Arvika - augmented reality for development, production and service, in I. C. Society, ed., '1st International Symposium on Mixed and Augmented Reality (ISMAR '02)', pp. 3–4, (2002)
- Garza, et al., Augmented Reality Application for the Maintenance of a Flapper Valve of a Fuller-kynion Type M Pump, *Procedia Computer Science*, Volume 25, pp. 154-160, (2013)
- Li, et al., Augmented Reality in IT Operation Management of Power System, 2016 13th Web Information Systems and Applications Conference (WISA), (2016)
- Mantzios, et al., Augmented Reality Applications Assisting Maintenance Activities in Extreme Environments: HCI Issues, *International Conference on Human-Computer Interaction*, pp. 613-618, (2014)
- Milgram, P., Takemura, H., Utsumi, A. and Kishino, F. (1994), Augmented reality: A class of displays on the reality-virtuality continuum, in SPIE, ed., 'Telemanipulator and Telepresence Technologies', Vol. 2351, pp. 282–292.
- Prassanna, K, How Augmented Reality Is Changing Industrial Asset Management, (2018)
- Oliveira, et.al, Augmented reality as a new level for maintenance efficiency, in 'The 2nd international workshop and congress on eMaintenance', Luleå University of Technology, pp. 49–55, (2012)
- Oliveira, et al., An Augmented Reality Application to Support Maintenance – Is It Possible (2012)
- Schwald, B. and de Laval, B., 'An augmented reality system for training and assistance to maintenance in the industrial context', *WSCG 11(1)*, 3–7, (2003)
- Van Krevelen, D. W. F. and Poelman, R., 'A Survey of Augmented Reality Technologies, Applications and Limitations', *The International Journal of Virtual Reality* 9(2), 1–20, (2010).



# Application the fuzzy TOPSIS method to assess and select a contractor from the point of view of occupational safety management

Joanna Tabor\*

*Faculty of Management, Czestochowa University of Technology, Dabrowskiego 69, 42-200 Czestochowa, Poland*

---

## Abstract

The objective of this work is to analyse the possibility to use ordered fuzzy numbers within the frameworks of the TOPSIS method to assess the contractor using selected work health and safety management system criteria. Selection of a contractor is a decision-making problem for a decision-maker as it involves many criteria. In many situations, these criteria may at the same time be highly different: qualitative, quantitative, stimulants, destimulants. Fuzzy number orientation points to the type of criterion which we have to do with while carrying out our assessment. In order to assess and select the contractor, six different work health and safety management system criteria were used: (1) number of persons employed in hazardous work environment conditions, (2) rate of occupational risk assessments completed, (3) number of persons employed in hazardous conditions with reference to whom hazards have been eliminated or reduced over the year down to the level that complies with the standard, (4) indicator of the organisational preventive system usage, (5) training procedure and workplace instruction conformance level, and (6) number of benefits on account of working in conditions that are detrimental or hazardous to health. The criteria and their weights were established taking into account the nature of installation and maintenance works being planned. As a source of information, we used Z-10 annual working conditions reports submitted by companies to GUS [Polish Central Statistical Office], and work health and safety procedures submitted by five contractors. As a result of our research work, we have established that the use of ordered fuzzy numbers within the frameworks of the TOPSIS method makes it possible to streamline the contractors being reviewed from the point of view of selected criteria, and to select the company which meets the adopted work health and safety criteria to the greatest extent.

*Keywords: Making decision; OHS management; Fuzzy Topsis*

---

## 1. Introduction

In view of widespread use of outsourcing of various activities as part of companies' business, one of the key issues when selecting the contractor company is for the contractor to provide for work safety. The literature on this subject indicates that the subcontractor's high accident rate primarily results from poor knowledge of workplace conditions and procedures (Clarke, 2003), tendency for subcontractors to initiate high risk activities (Blank et al., 1995), insufficient training or experience in safety assurance issues (Kochan et al., 1994), improper identification of hazards or improper assessment of risks (Salminen, 1995), insufficient safety awareness (Hon et al., 2010), economic pressure, and poor organisation of work processes (Quinlan and Mayhew, 2000). Since accidents at work disturb the normal functioning of both the company and its subcontractor, the issue of optimum selection of the contractor has become one of the key business decisions within the integrated safety management system (Holubová, 2016; Majerník et al., 2017).

Although the decision-making process constitutes an integral part of the work health and safety management system, the use of multi-criteria decision-making tools in this area is still hardly practiced and rarely described in the literature on the subject. However, one can find various reviews of the methods themselves and their practical applications in the literature. As an example, the work by Trzaskalik (2014) contains analysis of the most frequently used methods in terms of selecting the optimum method for a given type of task, while the work by Zamani-Sabzi et al. (2016) contains statistical and analytical comparison of such methods when used in the fuzzy environment.

---

\* Corresponding author. Tel.: +48 60 949 0906; fax: +48 34 325 0244.  
E-mail address: joanna.tabor@wz.pcz.pl

One of the most well-known and best described multi-criteria decision supporting methods is the TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) method. This is a tool that is used for linear ordering of variants in the decision-making process proposed by Hwang and Yoon (1981). One of this method's characteristic features is making use of the measure of relative distance from the best solution, which constitutes the pattern, and from the worst solution, which constitutes the anti-pattern, while its primary objective is to identify the variant which would be characterised by the maximum relative proximity to the pattern, and the minimum relative proximity to the anti-pattern. At the moment, the method that is used most frequently is the so-called fuzzy TOPSIS method introduced by Chen and Hwang (1992), which makes use of Zadeh's theory of fuzzy sets (1965) to solve available information ambiguity problems and assessment subjectivity issues. Currently, the basic application areas of the TOPSIS method include: logistics and supply chain management, production management, energy and resources management, and environmental management (Behzadian et al., 2012).

On the other hand, the Ordered Fuzzy Numbers model was proposed in 2002 by W. Kosiński, P. Prokopowicz, and D. Ślęzak (Kosiński et al., 2003). This model eliminates drawbacks of classical fuzzy numbers algebra based upon the extension principle according to Zadeh. A characteristic feature of the ordered fuzzy number is the fact that its orientation points to the type of the decision-making criterion which we have to do with. In case of the "loss"-type criterion, the fuzzy number's orientation is in the direction of the 0 value (the lower the value, the better); in case of the "profit"-type criterion, its orientation is in the direction of infinity (the higher the value, the better). Since quite different types of criteria, e.g. both stimulants and destimulants, tend to occur in the decision-making process, ordered fuzzy numbers seem to be a very good solution to such situations.

This work proposes an original application of the ordered fuzzy numbers and the TOPSIS method in the work safety management area.

## **2. Research methodology**

The objective of this work was to verify the possibility to use ordered fuzzy numbers, as part of the TOPSIS method, to assess and select the contractor in terms of varying work health and safety management system criteria.

Assessment criteria and their weights were established, taking into account the specificity of the planned installation and maintenance works and characteristics of the machinery installation, maintenance, and repair sector (C33) from the point of view of some of the main hazards and reasons for accidents at work. The above-mentioned sector is characterised by high rates of persons employed in hazardous work environment conditions (for 2016: 84.4 per 1000 employees), work strain (59.2), and mechanical factors (19.8) which are higher than the average in the Industrial Processing section (respectively: 75.8; 24.3; and 11.7), with the following hazards being especially significant in this area: excessive workload (27.8), work with particularly hazardous machines (21.2), and industrial dusts (20.0) (CSO, 2017a). Also, accident rates are higher than the average: In 2016, the indicator of fatal accident victims was 0.032 (per 1000 employees), and the indicator of serious accident victims was 0.09; whereas the basic reasons for accidents at work in this industry, besides incorrect employee behaviour, comprise: improper organisation of work and/or workplace (16.9% of all reasons for accidents at work), lack or inappropriate use of the material agent (9.3%), and inappropriate condition of the material agent used while performing the work (9.1%) (CSO, 2017b).

Taking the above into account, six varying criteria were selected in our contractor assessments:  $C_1$ - number of persons employed in hazardous work environment conditions per 1000 employees;  $C_2$ - rate of occupational risk assessments completed (in %);  $C_3$ - number of persons employed in hazardous conditions with reference to whom hazards have been eliminated or reduced over the year down to the level that complies with the standard per 1000 employees;  $C_4$ - indicator of the organisational preventive system usage (in %);  $C_5$ - training procedure and workplace instruction conformance level - the score-based assessment on a scale of 0 to 10, and  $C_6$ - number of benefits on account of working in conditions that are detrimental or hazardous to health. On the other hand, weights of the particular criteria were subjectively determined at the following levels:  $wC_1=0.15$ ,  $wC_2=0.25$ ,  $wC_3=0.15$ ,  $wC_4=0.15$ ,  $wC_5=0.10$  and  $wC_6=0.20$ . The highest weight was attributed to the rate of occupational risk assessments completed (0.25), considering that the specificity of the installation and maintenance works requires risk assessments to be performed much more frequently. The number of benefits on account of working in conditions that are detrimental or hazardous to health was also considered important, as it implied that hazard-prevention measures had already been taken.

As a source of information, we used Z-10 annual working conditions reports submitted by companies to GUS [Polish Central Statistical Office], as well as training procedures and workplace instructions submitted by five potential contractors from the machinery installation, maintenance, and repair sector. Contractor selection procedures were verified for conformance with procedures adopted by the selecting company (criterion  $C_5$ ), whereas Z-10 annual reports were used to determine values of the remaining assessment criteria. Despite the fact that these criteria were not expressed verbally, fuzzy sets were used due to uncertainty of information. In our analysis, we used the approach proposed by Rudnik and Kacprzak (2015), within the frameworks of which fuzzy assessments are produced by extending assessment ranges by fuzzy uncertainty ranges, which does not require any additional experts being engaged.

Calculations should be performed in line with the following procedure:

(1) Create a fuzzy decision-making matrix  $X$  using ordered fuzzy numbers:

$$X = \begin{bmatrix} x_{11} & x_{12} & \dots & x_{1N} \\ x_{21} & x_{22} & \dots & x_{2N} \\ \vdots & \vdots & \ddots & \vdots \\ x_{M1} & x_{M2} & \dots & x_{MN} \end{bmatrix} \quad (1)$$

Where:  $x_{ij} = (l_{ij} \ 1_{ij}^- \ 1_{ij}^+ \ p_{ij})$  ( $i = 1, 2, \dots, M; j = 1, 2, \dots, N$ ) are ordered fuzzy numbers (where:  $l$  – left, lower bound,  $p$  – right, upper bound). The fuzzy decision-making matrix is created based upon replacement of sharp assessments  $x_{ij}^*$  with assessments expressed using ordered fuzzy numbers  $x_{ij}$ .

(2) Create a standardized fuzzy matrix  $Z$ :

$$Z = \begin{bmatrix} z_{11} & z_{12} & \dots & z_{1N} \\ z_{21} & z_{22} & \dots & z_{2N} \\ \vdots & \vdots & \ddots & \vdots \\ z_{M1} & z_{M2} & \dots & z_{MN} \end{bmatrix}, \quad (2)$$

where:

$$z_{ij} = \begin{cases} \left( \frac{l_{ij}}{\max_i p_{ij}} \frac{1_{ij}^-}{\max_i p_{ij}} \frac{1_{ij}^+}{\max_i p_{ij}} \frac{p_{ij}}{\max_i p_{ij}} \right) & \text{when } C_j - \text{"profit"} - \text{type criterion} \\ \left( \frac{\min_i p_{ij}}{l_{ij}} \frac{\min_i p_{ij}}{1_{ij}^-} \frac{\min_i p_{ij}}{1_{ij}^+} \frac{\min_i p_{ij}}{p_{ij}} \right) & \text{when } C_j - \text{"loss"} - \text{type criterion} \end{cases} \quad (3)$$

(3) Create a weighted standardized fuzzy matrix  $V$ :

$$V = \begin{bmatrix} v_{11} & v_{12} & \dots & v_{1N} \\ v_{21} & v_{22} & \dots & v_{2N} \\ \vdots & \vdots & \ddots & \vdots \\ v_{M1} & v_{M2} & \dots & v_{MN} \end{bmatrix}, \quad (4)$$

where:  $v_{ij} = z_{ij} \times w_j$  ( $i = 1, 2, \dots, M; j = 1, 2, \dots, N$ )

Scalar vector of weights:  $w = [w_1, w_2, \dots, w_N]$ ,

where  $w_N \in \mathbb{R}$  ( $w_N > 0, n = 1, 2, \dots, N$ ) is the weight of the  $n$ -th criterion, whereby:  $w_1 + w_2 + \dots + w_N = 1$

(4) Find pattern  $A^+$  and anti-pattern  $A^-$  to assess each criterion, whereby:

$$A^+ = (v_1^+, v_2^+, \dots, v_N^+), \quad (6)$$

where:  $v_j^+ = (\max_i l_{vij}, \max_i 1_{vij}^-, \max_i 1_{vij}^+, \max_i p_{vij})$ ,  $j = 1, 2, \dots, N$  and

$$A^- = (v_1^-, v_2^-, \dots, v_N^-), \quad (7)$$

where:  $v_j^- = (\min_i l_{vij}, \min_i 1_{vij}^-, \min_i 1_{vij}^+, \min_i p_{vij})$ ,  $j = 1, 2, \dots, N$

(5) Calculate the distance of assessments of the particular variants from the pattern and from the anti-pattern using the following correlations:

$$d_i^+ = \sum_{j=1}^N d(v_{ij}, v_j^+) \quad \text{and} \quad d_i^- = \sum_{j=1}^N d(v_{ij}, v_j^-) \quad \text{for } i = 1, 2, \dots, M \quad (8)$$

where:

$$d(A, B) = \sqrt{\frac{1}{4}[(l_A - l_B)^2 + (1_A^- - 1_B^-)^2 + (1_A^+ - 1_B^+)^2 + (p_A - p_B)^2]}, \quad (9)$$

for:  $A = (l_A \ 1_A^- \ 1_A^+ \ p_A)$  ;  $B = (l_B \ 1_B^- \ 1_B^+ \ p_B)$

(6) Determine the synthetic measure of assessments of variants  $CC_i$  using relative proximity of assessments of variants to the pattern and to the anti-pattern:

$$CC_i = \frac{d_i^-}{d_i^+ + d_i^-}, \quad i = 1, 2, \dots, M \quad (10)$$

The lower the distance of assessment from the pattern, and at the same time the higher the distance from the anti-pattern, the closer the value of the measure is to 1.

(7) Create a ranking for  $M$  variants based upon linear ordering of synthetic measures:  $CC_i$ , where  $i = 1, 2, \dots, M$ .

The starting point for these calculations is the non-fuzzy (sharp) decision-making matrix of assessments of “ $i$ ” variants with respect to “ $j$ ” criteria.

### 3. Results

Table 1 juxtaposes information concerning values of the particular criteria  $C_1$ - $C_6$  for the assessed alternatives (contractors)  $A_1$ - $A_5$ , obtained from reports and based on verification of procedures.

Table 1. Input data for assessments of alternatives

	$C_1$	$C_2$	$C_3$	$C_4$	$C_5$	$C_6$
$A_1$	135	71	38	36	6	6
$A_2$	146	63	46	49	8	5
$A_3$	118	43	35	28	5	3
$A_4$	122	52	41	41	6	4
$A_5$	129	60	40	31	5	5

Based on the input data, using formula (1), the fuzzy decision-making matrix was created, which contained fuzzy values of assessments of alternatives against the particular criteria – Table 2. In line with characteristics of the selected criteria, “loss”-type criteria (the lower the value, the better) were  $C_1$ - number of persons employed in hazardous work environment conditions per 1000 employees, and  $C_6$ - number of benefits on account of working in conditions that are detrimental or hazardous to health, whereas the remaining criteria were “profit”-type criteria (the higher the value, the better).

Table 2. Values from the fuzzy decision-making matrix

	$C_1$				$C_2$				$C_3$			
	$l_{11}$	$l_{11}^-$	$l_{11}^+$	$p_{11}$	$l_{12}$	$l_{12}^-$	$l_{12}^+$	$p_{12}$	$l_{13}$	$l_{13}^-$	$l_{13}^+$	$p_{13}$
$A_1$	165	145	125	105	56	66	76	86	23	33	43	53
$A_2$	176	156	136	116	48	58	68	78	31	41	51	61
$A_3$	148	128	108	88	28	38	48	58	20	30	40	50
$A_4$	152	132	112	92	37	47	57	67	26	36	46	56
$A_5$	159	139	119	99	45	55	65	75	25	35	45	55

	$C_4$				$C_5$				$C_6$			
	$l_{14}$	$l_{14}^-$	$l_{14}^+$	$p_{14}$	$l_{15}$	$l_{15}^-$	$l_{15}^+$	$p_{15}$	$l_{16}$	$l_{16}^-$	$l_{16}^+$	$p_{16}$
$A_1$	21	31	41	51	5	5.5	6.5	7	7.5	6	6	4.5
$A_2$	34	44	54	64	7	7.5	8.5	9	6.5	5	5	3.5
$A_3$	13	23	33	43	4	4.5	5.5	6	4.5	3	3	1.5
$A_4$	26	36	46	56	5	5.5	6.5	7	5.5	4	4	2.5
$A_5$	16	26	36	46	4	4.5	5.5	6	6.5	5	5	3.5

Based upon fuzzy values of assessments of alternatives against the particular criteria, using formulas (2) and (3), we calculated fuzzy standardised values of assessments against the particular criteria – Table 3.

Table 3. Values from the standardized fuzzy decision-making matrix

	$C_1$				$C_2$				$C_3$			
	$l_{11}$	$l_{11}^-$	$l_{11}^+$	$p_{11}$	$l_{12}$	$l_{12}^-$	$l_{12}^+$	$p_{12}$	$l_{13}$	$l_{13}^-$	$l_{13}^+$	$p_{13}$
$A_1$	0.533	0.607	0.704	0.838	0.651	0.767	0.884	0.884	0.377	0.541	0.705	0.869
$A_2$	0.5	0.564	0.647	0.759	0.558	0.674	0.791	0.791	0.508	0.672	0.836	1.0
$A_3$	0.595	0.688	0.815	1.0	0.326	0.442	0.558	0.558	0.328	0.492	0.656	0.82
$A_4$	0.579	0.667	0.786	0.957	0.43	0.547	0.663	0.663	0.426	0.59	0.754	0.918
$A_5$	0.553	0.633	0.739	0.889	0.523	0.64	0.756	0.756	0.41	0.574	0.738	0.902

	$C_4$				$C_5$				$C_6$			
	$l_{14}$	$l_{14}^-$	$l_{14}^+$	$p_{14}$	$l_{15}$	$l_{15}^-$	$l_{15}^+$	$p_{15}$	$l_{16}$	$l_{16}^-$	$l_{16}^+$	$p_{16}$
$A_1$	0.328	0.484	0.641	0.797	0.556	0.611	0.722	0.778	0.2	0.25	0.25	0.333
$A_2$	0.531	0.688	0.844	1.0	0.778	0.833	0.944	1.0	0.231	0.3	0.3	0.429
$A_3$	0.203	0.359	0.516	0.672	0.444	0.5	0.611	0.667	0.333	0.5	0.5	1.0
$A_4$	0.407	0.563	0.719	0.875	0.556	0.611	0.722	0.778	0.273	0.375	0.375	0.6
$A_5$	0.25	0.406	0.563	0.719	0.444	0.5	0.611	0.667	0.231	0.3	0.3	0.429

Then, taking into account the established weights of the particular criteria and using formulas (4) and (5), we calculated weighted fuzzy standardised values of assessments against the particular criteria – Table 4.

Table 4. Values from the weighted standardized fuzzy decision-making matrix

	$C_1$				$C_2$				$C_3$			
	$l_{11}$	$l_{11}^-$	$l_{11}^+$	$p_{11}$	$l_{12}$	$l_{12}^-$	$l_{12}^+$	$p_{12}$	$l_{13}$	$l_{13}^-$	$l_{13}^+$	$p_{13}$
$A_1$	0.08	0.091	0.106	0.126	0.098	0.115	0.133	0.15	0.094	0.135	0.176	0.217
$A_2$	0.075	0.085	0.097	0.114	0.084	0.101	0.119	0.136	0.127	0.168	0.209	0.25
$A_3$	0.089	0.103	0.122	0.15	0.049	0.066	0.084	0.101	0.082	0.123	0.164	0.205
$A_4$	0.087	0.1	0.118	0.143	0.065	0.082	0.099	0.117	0.107	0.148	0.189	0.23
$A_5$	0.083	0.095	0.111	0.133	0.078	0.096	0.113	0.131	0.102	0.143	0.184	0.225

	$C_4$				$C_5$				$C_6$			
	$l_{14}$	$l_{14}^-$	$l_{14}^+$	$p_{14}$	$l_{15}$	$l_{15}^-$	$l_{15}^+$	$p_{15}$	$l_{16}$	$l_{16}^-$	$l_{16}^+$	$p_{16}$
$A_1$	0.066	0.097	0.128	0.159	0.083	0.092	0.108	0.117	0.02	0.025	0.025	0.033
$A_2$	0.106	0.138	0.169	0.2	0.117	0.125	0.142	0.15	0.023	0.03	0.03	0.043
$A_3$	0.041	0.072	0.103	0.134	0.067	0.075	0.092	0.1	0.033	0.05	0.05	0.1
$A_4$	0.081	0.113	0.144	0.175	0.083	0.092	0.108	0.117	0.027	0.038	0.038	0.06
$A_5$	0.05	0.081	0.113	0.144	0.067	0.075	0.092	0.1	0.023	0.03	0.03	0.043

Based upon the weighted standardised fuzzy decision-making matrix, we identified the pattern using formula (6): (0.089 0.103 0.122 0.15; 0.098 0.115 0.133 0.15; 0.127 0.168 0.209 0.25; 0.106 0.138 0.169 0.2; 0.117 0.125 0.142 0.15; 0.033 0.05 0.05 0.1); and the anti-pattern using formula (7): (0.075 0.085 0.097 0.114; 0.049 0.066 0.084 0.101; 0.082 0.123 0.164 0.205; 0.041 0.072 0.103 0.134; 0.067 0.075 0.092 0.1; 0.02 0.025 0.025 0.033). Using formulas (8) and (9), we calculated the particular assessments' distance from the pattern and from the anti-pattern – Table 5, and then, based upon formula (10), we calculated synthetic measures of assessments  $CC_1$  for the particular contractors  $A_1$ - $A_6$  – Table 6.

Table 5. Assessment's distance from the pattern and from the anti-pattern

	Distances from the pattern						
	$C_1$	$C_2$	$C_3$	$C_4$	$C_5$	$C_6$	$d_j^+$
$A_1$	0.016	0	0.033	0.041	0.034	0.038	0.162
$A_2$	0.025	0.014	0	0	0	0.032	0.072
$A_3$	0	0.049	0.045	0.066	0.05		0.210
$A_4$	0.004	0.033	0.02	0.025	0.034	0.022	0.139
$A_5$	0.011	0.019	0.025	0.056	0.05	0.032	0.194

	Distances from the anti-pattern						
	$C_1$	$C_2$	$C_3$	$C_4$	$C_5$	$C_6$	$d_j^-$
$A_1$	0.008	0.049	0.028	0.025	0.017	0	0.127
$A_2$	0	0.035	0.058	0.066	0.05	0.006	0.215
$A_3$	0.025	0	0.019	0	0	0.038	0.083
$A_4$	0.02	0.016	0.039	0.041	0.017	0.017	0.149
$A_5$	0.014	0.03	0.035	0.009	0	0.006	0.094

Table 6. Final ranking of companies

	$A_1$	$A_2$	$A_3$	$A_4$	$A_5$
$CC_1$	0.439	0.750	0.284	0.518	0.327
No.	3	1	5	2	4

The final ranking of companies, as in Table 6, suggests that in view of such assessment criteria that were adopted, and such relation of their significance that was established, company  $A_2$  turned out to be the best contractor to perform the planned installation and maintenance works from the point of view of work health and safety assurance, although it had the highest value of indicator  $C_1$ , and a high value of indicator  $C_6$ .

#### 4. Summary

As a result of our research work, we have established that the use of ordered fuzzy numbers as part of the TOPSIS method makes it possible to arrange the analysed contractors in order from the standpoint of the established criteria, and to select the contractor who meets the adopted varying work health and safety criteria to the greatest extent. Obviously, the way these criteria are selected depends on what the decision-maker actually needs. In the same way, the significance relation between weights of these criteria may look different than in our research. One of advantages of this method is

its simplicity and possibility to make calculations using the most popular spreadsheets. Although the TOPSIS method is one of the most widely used and best described ranking methods, the use of ordered fuzzy numbers has broadened this method's application range to the areas that have been poorly represented so far, such as, for instance, the area of the work health and safety management system. We hope that this work will inspire its readers to search for further applications of the fuzzy TOPSIS method, both in this area and in the area of using ordered fuzzy numbers within the frameworks of other multi-criteria decision-making methods.

## References

- Behzadian, M., Khanmohammadi Otaghsara, S., Yazdani, M., Ignatius, J., A state-of the-art survey of TOPSIS applications, *Expert System Applied*, Vol.39, pp. 13051-13069, (2012).
- Blank, V.L.G., Andersson, R., Linden, A., Nilsson, B.C., Hidden accident rates an patterns in the Swedish mining industry due to involvement of contractor workers, *Safety Science*, Vol.21, No.1, pp.23-35 (1995).
- Chen, S.J., Hwang, C.L., Fuzzy Multiple Attribute Decision Making: Methods and Applications, Springer, Berlin, (1992)
- Clarke, S., The contemporary workforce, implications for organisational safety culture, *Personnel Review*, Vol.32 No.1, pp. 40-57, (2003).
- CSOa, *Working Conditions in 2016*, Statistical Information and Elaborations, Central Statistical Office, Warsaw, (2017).
- CSOb, *Accidents at work in 2016*, Statistical Information and Elaborations, Central Statistical Office, Warsaw, (2017).
- Holubová, V., Integrated Safety Management Systems, *Polish Journal of Management Studies*, Vol.14, No.1, pp.106-118, (2016).
- Hon, C.K.H., Chan, A.P.C., Wong, F.K.W., Analysis for the causes of accidents of repair, maintenance, alteration and addition works in Hong Kong, *Safety Science*, Vol.7, No.48, pp. 894-901, (2010).
- Hwang, C.L., Yoon, K., Multiple Attribute Decision Making Methods and Applications, Springer, Berlin Heidelberg, (1981).
- Kochan, T.A., Smith, M., Wells, J.C., Rebitzer, J.B., Human resource strategies and contingent workers: the case of safety and health in the petrochemical industry, *Human Resource Management*, Vol.33, No.1, pp.55-77, (1994).
- Kosiński, W., Prokopowicz, P., Ślęzak, D., 2003, Ordered fuzzy numbers, *Bulletin of the Polish Academy of Sciences Mathematic*, Vol.52, No.3, pp.327-339, (2003).
- Majerník, M., Daneshjo, N., Chovancová, J., Sančiová, G., Design of integrated systems according to the revised ISO standards, *Polish Journal of Management Studies*, Vol.15, No.1, pp.135-143, (2017).
- Quinlan, M., Mayhew, C., Precarious Employment, work re-organisation and the fracturing of OHS management, [in:] Frick K., Jensen P.L., Quinlan M., Wilthagen T. (Eds.) *Systematic Occupational Health and Safety Management: Perspectives on an International Development*, Pergamon, Amsterdam, pp.175-198, (2000).
- Rudnik, K., Kacprzak, D., 2015, Rozmyta metoda TOPSIS wykorzystująca skierowane liczby rozmyte, [W:] *Innowacje w zarządzaniu i inżynierii produkcji*, R. Knosala (Ed.), Oficyna Wydawnicza PTZP, Opole, pp.958-968, (2015).
- Salminen, S., Serious occupational accidents in the construction industry, *Construction Management and Economics*, Vol.13, No.4, pp. 299-306, (1995).
- Zadeh L.A., 1965, Fuzzy sets, *Information and Control*, Vol.8, No.3, pp.338-353, (1965).
- Zamani-Sabzi, H., King, J.P., Gard, Ch.C., Abudu, S., Statistical and analytical comparison of multi-criteria decision-making techniques under fuzzy environment, *Operations Research Perspectives*, Vol.3, pp.92-117, (2016).

# Limitations and error mitigation for mine climate models with no thermal history component

G. Danko<sup>a,b,\*</sup>

<sup>a</sup>University of Nevada, Reno, 1664 N Virginia St, Reno, NV, 89557, USA

<sup>b</sup>University of Miskolc, Miskolc-Egyetemvaros, 3515, Pf. 2, Hungary

---

## Abstract

Currently available, commercial mine ventilation software models usually do not have the “thermal history effect” (also known as thermal flywheel effect) solver. It is well recognized that any mine climate model without thermal history component for thermal–humidity simulations will give erroneous result, however, such models are rarely available for the mine ventilation engineer. The goal of this study is to find the best way of using the simple thermal-humidity simulation models without the thermal history component for reduced simulation error in the thermal design of mine ventilation.

Three models are used for the testing a proposed simplification application for dynamic thermal-humidity simulations in underground mine. The first model is set up for the accurate solution, complete with the thermal history component, processing past and current temperature and heat flow data. Results from the first model are used as the reference for comparison. The second model is configured as a conventional mine climate model without including the thermal history component, simplifying the past temperatures with a step-change function and calculating the strata heat from the Gibson function type solution. The third model is set up according to a new, simplified, proposed method for error mitigation, using the superposition of two step-change solutions only. A long, single drift example is used for the numerical study for comparison of the three model results. Conclusions are drawn with recommendations to the engineers for improving the simplified, step-change-type numerical simulation tool for mine ventilation and climate design.

*Keywords:* mine climate; thermal simulation; temperature variation; thermal flywheel effects

---

## 1. Introduction

Air temperature and humidity are of great concern for safety and health of the miners at the work face in deep and hot underground mines. The thermal design of the mine must incorporate various heat, mass and momentum transport components such as advection, convection, conduction radiation and accumulation between the air, strata, machinery and people working underground (Danko, 2016). Traditional mine ventilation and climatic models (e.g., VnetPC and Climsim, 2018) can only be used with limited accuracy regarding the seasonal and daily maximum temperatures expected to be within regulatory limits, such as below 27 °C effective temperature in most countries. Following the early efforts (Vost, 1977), improved models have been emerging (Bluhm et al., 2001; Danko, 2013; Ventsim, 2018). In search for solution to dynamic simulations with time, the research community in mine climate has turned into the Computational Fluid Dynamic (CFD) tools (Cradle, 2012; Fluent, 1997), a difficult avenue in computational time and capacity. While CFD models are good choices for the laminar or turbulent air flow in the mine tunnels and shafts, the heat and moisture flow model in the strata must be coupled to the solution, a difficult task. Similarly, Porous-Media Transport Models for the strata, such as NUFT (Nitao, 2000) or TOUGH2 (Pruess et al., 1999) are likewise complex to be coupled for solving the conjugate transport problem for the air flow together with the rock mass around it. A new method is introduced for the coupled solution using the Numerical Transport Code Functionalization (NTCF) technique (Danko, 2006; NTCF, 2008, 2013) accelerating the computation by several orders of magnitudes.

---

\* Corresponding author. Tel.: 1-775-784-4284.  
E-mail address: danko@unr.edu.



Such solutions, however, may not be available commercially to the practicing designer or operator of a mine. The goal of the present study is show a simplified solution using the basic technique of step-change-type temperature history representation of the time-dependent temperature history in the rock strata everywhere and every time instant during the simulation time. The method is introduced in the course of a mine climate simulation example. First, a correct solution is described as Case 1, using the NTCF method for modelling the time-dependent heat flow in the strata with a 1-day time division for 12 years, coupled to the advection, convection and thermal accumulation model of the airway in a 10,000 m long drift in the mine. Second, the correct, NTCF model-element for the strata heat is replaced with a Step-Change-Function (SCF) model as Case 2, similarly to the method, used in a previous comparative study (Danko, 2013) for error analysis. Third, the SCF model element is refined with a Dual-Step-Change-Function (DSCF) model as Case 3 for comparison with the correct, NTCF-based solution as well as with the SCF solution for methods evaluation.

## 2. Model description

Air temperature and humidity variations are modelled in a 10,000 m horizontal drift driven in hard rock 1,000 m below the surface at  $T_{VR}=44$  °C] virgin rock temperature. The thermal conductivity, density, and specific heat of the rock strata are 3 W/m/K, 2,700 kg/m<sup>3</sup> and 845 J/kg/K, respectively. The cross section and the perimeter of the drift are 25 m<sup>2</sup> and 17.72 m, respectively, closely matching a metal mine in Nevada, USA. Line-averaged heat load from Diesel haulage transportation is assumed at a constant rate of 60.6 W/m accompanied by line-load-type water vapor emission of  $3.27 \times 10^{-6}$  kg/s/m from the engine. The drift wall is kept partially wet at 0.24 wetness factor. The entire perimeter is also split into dry and the wet segments of 74% and 24%, respectively, defining two different wall temperatures at each cross section,  $T_{w,D}(x,t)$  and  $T_{w,W}(x,t)$ .

The air entering the drift is assumed to be heated by a forcing fan, dissipating 991 [kW] compression energy adiabatically into the air flow; and autocompression of 588.6 kW due to descending to 1,000 m depth through a vertical intake shaft. The heat transport in the 1,000 m vertical shaft is otherwise excluded, assuming perfect thermal insulation along its wall. The model arrangement is shown in Figure 1. The input air from the outside environment enters the horizontal drift section before the node of the heat sources from the fan and autocompression. The variable temperature of the air, following the measured, daily mean temperature, is accessed from the weather data for the region (Danko and Lu, 2018) for the entire time period of 12 years, defining a temporal discretization of 1 day and 4,383 time instants. The thermal model simulates the variable temperature field inside the drift along its length at 1,000 points (defining a spatial discretization of 10 m) in the air at 1,000 points; on the drift wall at 2,000 points (1,000 each for the wet and dry segments), and in the rock wall with 2,000 elements of continuous, analytical models between the wall points and the virgin rock area assumed to be at infinite distance in radial direction.

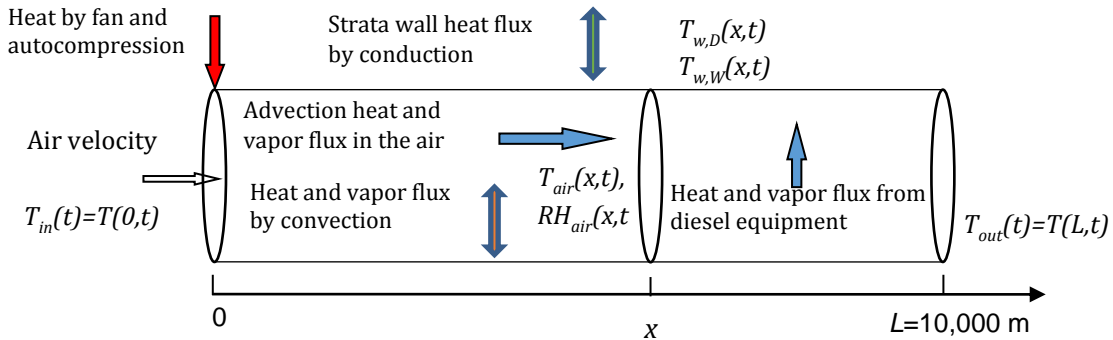


Figure 1. A single drift example with heat and water vapor fluxes transported by advection in the air, convection on the wall, and conduction in the strata.

### a. Case 1. Wall heat flux model-element with the thermal history component

The NTCF modelling technique is used for calculating the time-dependent wall heat flux for the variable wall temperature with thermal history as follows (Danko, 2006):

$$q_w(t_i) = q_w(0) + \sum_{j=1}^i a_1(i,j) [T_w(t_j) - T_{VR}] \quad (1)$$

In (1),  $a_1(i,j)$  are the elements of matrix  $\mathbf{h}_1 = \{a_1(i,j)\}$ ,  $\mathbf{h}_1 \in R^2$ , an  $M \times M$  matrix calculated by the NTCF procedure for a  $[0, t_M]$  time interval for  $M$  time divisions (Danko, 2006). The full form of the  $\mathbf{h}_1$  matrix is of a lower triangular, incorporating coefficients in row  $i$  for all  $j \in [0, T_w(t_i)]$  wall temperatures as contributing history data for the  $q_w(t_i)$  wall heat flux. In matrix-vector notations, (1) reads:

$$\mathbf{q}_w = \mathbf{q}_0 + \mathbf{h}_1 [\mathbf{T}_w - T_{VR}] \quad (2)$$

where  $\mathbf{q}_w = \{q_w(t_i)\}$  and  $\mathbf{T}_w = \{T_w(t_i)\}$  are vectors of the temporal values of the variables.

b. *Case 2. Wall heat flux model-element with the SCF thermal history component*

The full NTCF matrix model can be used to emulate the SCF history by replacing the lower-triangular matrix with a diagonal matrix by summation in each line:

$$a_2(i, i) = \sum_{j=1}^i a_1(i, j); \quad h_2 = \begin{cases} a_2(i, i), & \text{for } \forall i \in [1, M] \\ 0, & \text{for } \forall i \neq j \end{cases} \quad (3)$$

Diagonal matrix  $h_2$  ignores the history temperature values in the  $T_w$  vector, therefore, the expression in (2) may be used for  $q_w$  for the Case 2 model as  $q_w = q_0 + h_2 [T_w - T_{VR}]$ . Such a recognition helps testing the SCF model against the full NTCF model without changing the universal version of the core solution engine in the Multiflux model (Danko, 2016).

c. *Case 3. Wall heat flux model-element with the DSCF thermal history component*

The full NTCF matrix model can be used to emulate the simplified DSCF history by replacing elements of two strips in the lower-triangular matrix. As a simple example, one strip is chosen as the original value of the diagonal elements in  $h_1$ ; while the other step is defined as the average value of the remaining elements in each row for a given width of the trip,  $N$ . The algorithm of the  $h_3$  matrix derived from the full NTCF matrix  $h_1$  is as follows:

$$a_3(i, i) = a_1(i, i); \quad a_3(i, j) = \sum_{l=i-N+1}^{i-1} \frac{a_1(i, l)}{N} h_2 = \begin{cases} a_2(i, i), & \text{for } \forall i \in [1, M] \\ a_2(i, j), & \text{for } j \in [i - N + 1, i - 1] \text{ for } \forall i \neq j \\ 0 & \text{elsever} \end{cases} \quad (4)$$

Dual-strip matrix  $h_3$  modifies the history temperature values in the  $T_w$  vector according to the dual step-change-type history scheme, therefore, the expression in (2) may be used for  $q_w$  for the Case 3 model as  $q_w = q_0 + h_3 [T_w - T_{VR}]$ . Once again, the most universal version of the core solution engine in the Multiflux model is used without major modification in the comparison study. This technique eliminates the need for any software modification and possible mistakes in the execution of the study.

### 3. Numerical results

The daily average temperature variation results for the Cases 1, 2, and 3 models are shown in Figures 2a, 3a and 4a for the entire 12 year time period at the  $x=0$  m intake, and at 1,000 m, 2,000 m, 5,000 m and 10,000 m distances from the entry point. Enlargements are shown in Figures 2b, 3b and 4b for the last 1.5 year time period. The Case 1 model results are used as the baseline reference. The absolute error in temperature in the Case 2 and Case 3 models relative to Case 1 are shown in Figures 5a and 5b, respectively. The temperature error in per cent in Case 2 and Case 3 models are depicted in Figures 6a and 6b, respectively.

The baseline humidity variations in the air from the Case 1 model are shown in Figures 7a and 7b in absolute humidity fraction and relative humidity forms, respectively. The relative humidity variations are depicted in Figures 8a and 8b from the Case 2 and Case 3 models, respectively. The relative per cent errors in relative humidity in the Case 2 and Case 3 models in comparison to the Case 1 model results are shown in Figures 9a and 9b.

### Discussion of the results

The temperature solution  $T_{air}(x, t)$  from the Case 1 model with the full NTCF function for the wall heat flux gives the most reasonable variation showing a time delay and amplitude attenuation with increasing length, shown in Figures 2a and 2b. The single step-change solution in Case 2, shown in Figures 2a and 2b, gives no time delay and noisy results. The error from the Case 2 model, depicted in Figures 5a and 6a, is significant in both absolute temperature and relative per cent values to be acceptable without criticism in engineering design or analysis. The errors are variable with time and alternate between positive and negative values. The error in relative humidity is also quite high in the Case 2 model, shown in Figure 9a.

The results from the Case 3 model for both temperature and relative humidity variations are much closer to those from the Case 1 reference model. Although only two distinct step changes are modelled, even a time delay is noticeable with increasing distance in Figure 2a and 2b. The errors are also much lower than those in the Case 2 model results.

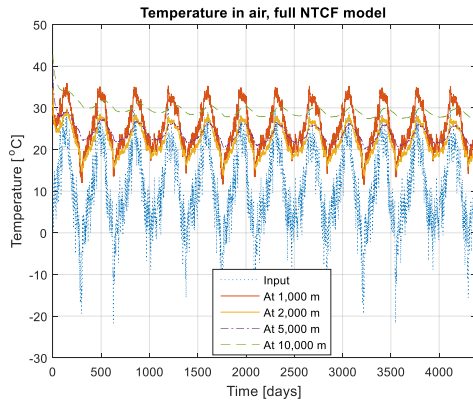


Figure 2a. Temperature in Case 1.

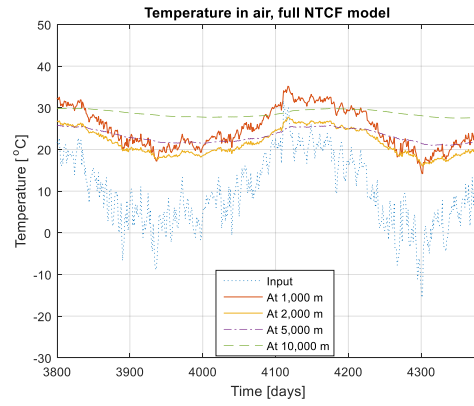


Figure 2b. Enlargement in Figure 2a.

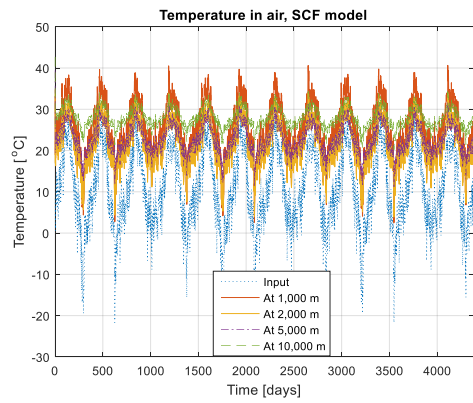


Figure 3a. Temperature in Case 2.

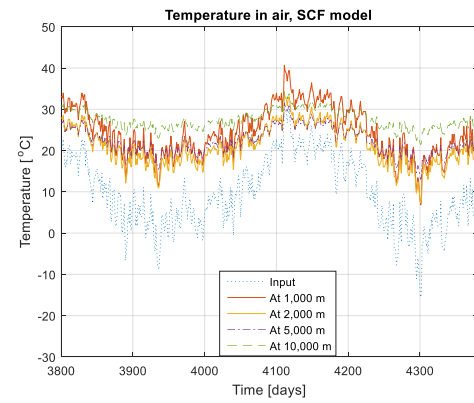


Figure 3b. Enlargement in Figure 3a.

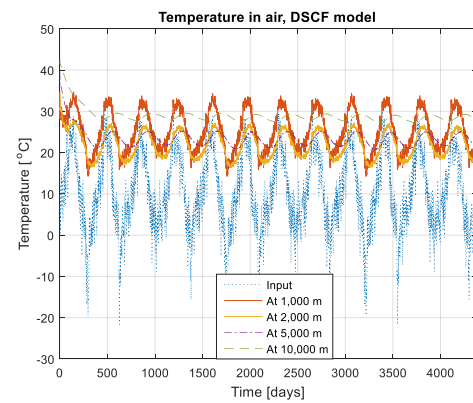


Figure 4a. Temperature in Case 3.

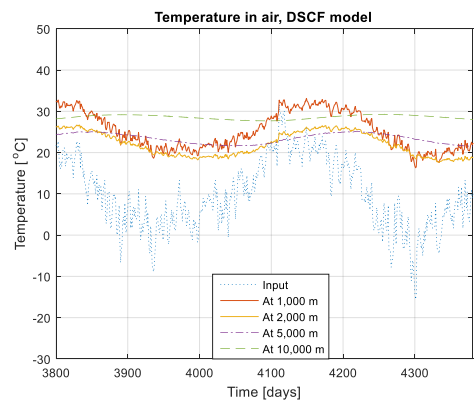


Figure 4b. Enlargement in Figure 4a.

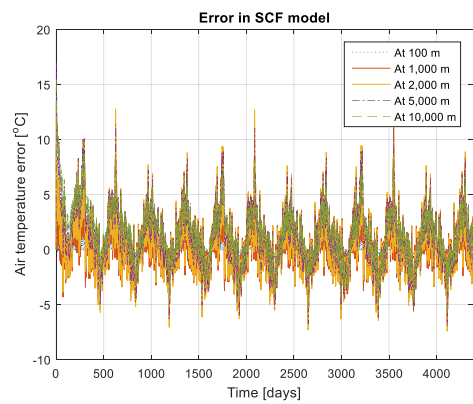


Figure 5a. Temperature error in Case 2 model.

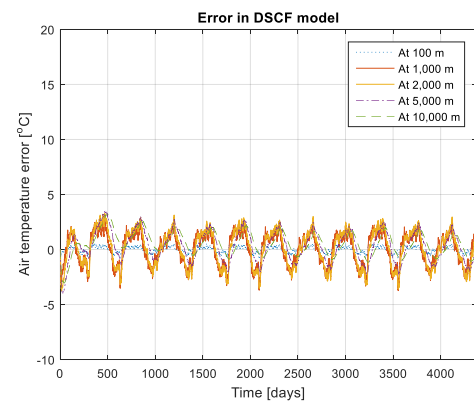


Figure 5b. Temperature error in Case 3 model.

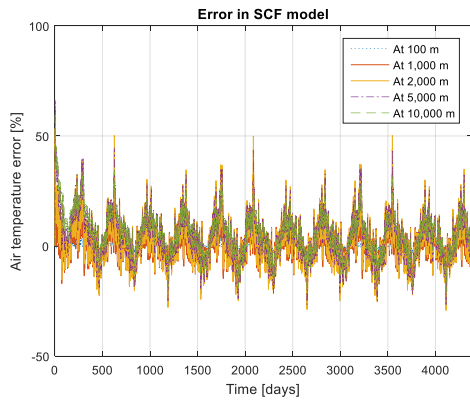


Figure 6a. Relative error in the Case 2 model.

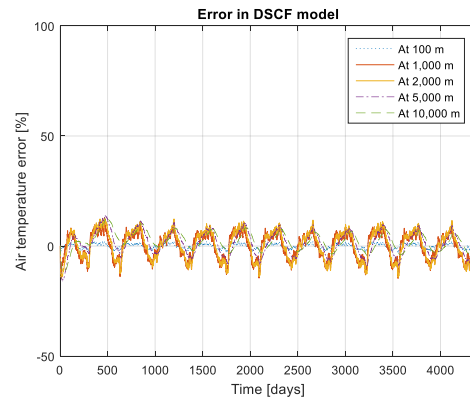


Figure 6b. Relative error in the Case 3 model.

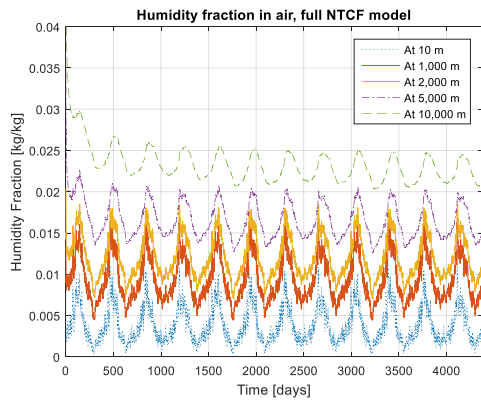


Figure 7a. Humidity fraction in the Case 1 model.

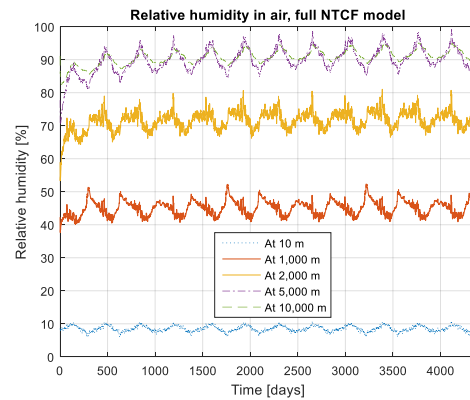


Figure 7b. Relative humidity in the Case 1 model.

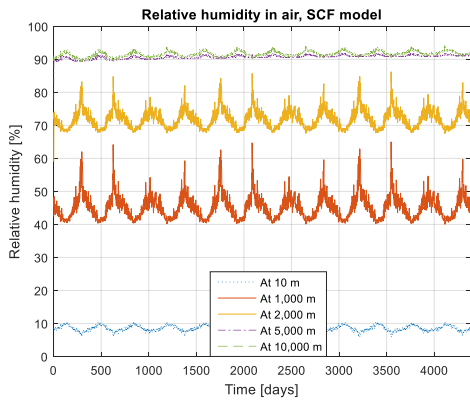


Figure 8a. Relative humidity in the Case 2 model.

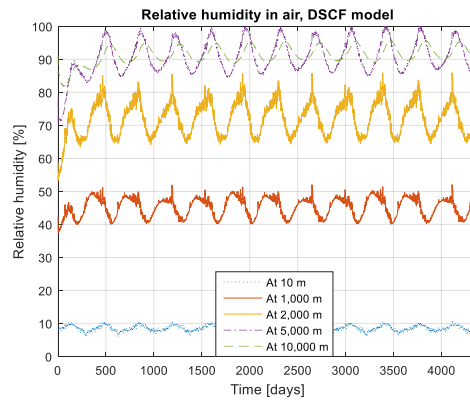


Figure 8b. Relative humidity in the Case 3 model.

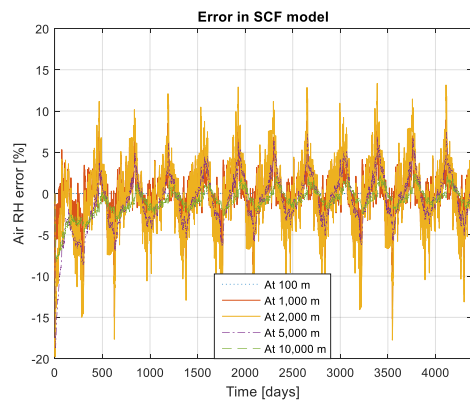


Figure 9a. Relative error in the Case 2 model.

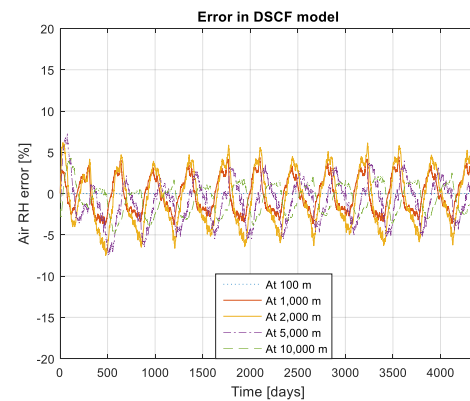


Figure 9b. Relative error in the Case 3 model.

## **Concluding remarks**

- A hypothesis has been proven by the numerical study regarding achieving significant improvement in modelling accuracy by applying two distinct step changes, instead of only one, in the temperature history of the wall temperature of the drift.
- A model analysis with two distinct time steps is not excessive to perform manually. However, such an algorithm is not readily available for the user making the improved method in Case 3 difficult to implement in mine climate simulations.
- The implementation of the Case 3 model in the MULTIFLUX model is simple and straightforward on the basis of the availability of the full NTCF matrix solution for the wall heat flux. However, it would be quite counter-productive to scale back a fully-completed, Case 1 model into an approximate, Case 3 model.
- It is interesting to note that the run time of the Case 3 model in MULTIFLUX has been much longer than that for the Case 1 model or the Case 2 model. Difficulty in convergence may be caused by the mathematical fact that the wall temperature history is affected backward by averaging over the second step-change interval.

## **Acknowledgements**

A research grant from National Institute of Occupational Safety and Health (NIOSH), U.S.A., is gratefully recognized.

The research was thankfully supported by the GINOP-2.3.2-15-2016-00010 "Development of enhanced engineering methods with the aim at utilization of subterranean energy resources" project of the Research Institute of Applied Earth Sciences of the University of Miskolc in the framework of the Széchenyi 2020 Plan, funded by the European Union, co-financed by the European Structural and Investment Funds.

## **References**

- Bluhm, S J, Marx, W M, Von Glehn, F H, and Biffi, M, (2001). "VUMA mine ventilation software." *Journal of the Mine Ventilation Society of South Africa*, Vol 54.
- Cradle, (2012). *Thermofluid Analysis System with unstructured Mesh Generator SC/Tetra Version 10 User's Guide*, Software Cradle Co., Ltd.
- Danko, G., (2006). "Functional or Operator Representation of Numerical Heat and Mass Transport Models," *ASME J. of Heat Transfer*, Vol. 128, p. 162-175.
- Danko, G., (2013). "Subsurface Flow and Transport Process Model for Time-Dependent Mine Ventilation Simulations." *Mining Technology*, Vol. 122, No. 3. p. 134-144.
- Danko, G., (2016), *Model Elements and Network Solutions of Heat, Mass and Momentum Transport Processes*. Springer-Verlag GmbH Germany, ISBN 798-3-662-52929-4, (Print), ISBN 798-3-662-52931-7 (eBook).
- Danko, G., and Lu, C., (2018), "Variable daily air temperature model for analysis and design." *J. Applied Mathematics*, <http://www.scirp.org/journal/am>, ISSN Online: 2152-7393; ISSN Print: 2152-7385., 2018, 9, p.1-24.
- Fluent 5.5, ANSYS, (1997). Copyright Fluent Inc., Lebanon, NH., <http://www.ansys.com/products/fluids/ansys-fluent>.
- Nitao, J., (2000). "NUFT, Flow and Transport code V3.0s." *Software Configuration Management*, Yucca Mountain Project – STN: 10088-3.0S-00. Prepared at Lawrence Livermore National Laboratory.
- NTCF, U.S. Patent No. 7610183B2, (2008), and U.S. Patent No. 8396693 B2 (2013), "Multiphase physical transport modeling method and modeling system."
- Pruess, K., C. Oldenburg, and G. Moridis, (1999). "TOUGH2 User's Guide, Version 2.0." Report LBNL-43134, Lawrence Berkeley National Laboratory, Earth Sciences Division, Berkeley, California.
- Starfield A., Dickson A., Johnston H. and Rallis C., (1964). "The Use of Computers in Heat-Flow Problems in Underground Workings," *Quarterly of the Colorado School Of Mine*, p. 940-969.
- Ventsim Software, (2018). *Ventsim Visual™ User Guide Version 5.0* in: Chasm Consulting, Brisbane, <http://www.ventsim.com>.
- VnetPC (2018) *VnetPC (2018). User's Manual and Tutorial*, Mine Ventilation Services, Inc., <https://www.mvsengineering.com/files/NewVNet/VNet.pdf>.
- Vost K., (1977). "Rapid Changes of Air Temperature in Underground Airways," *Journal of the South American Institute of Mining and Metallurgy*, p. 262-268.

## Developing a model of occupational health program

Zerbes Mihai-Victor<sup>a</sup>, Cioca Lucian-Ionel<sup>a</sup>, Neamu Vasilica-Silvia\*

<sup>a</sup> “Lucian Blaga” University of Sibiu, 10, Victoriei Bd, Sibiu, 550024, România

---

### Abstract

The first author of this paper noted last year, in a workshop at the MSE 2017 international conference on OSH-related topics, that none of the experts involved and any papers on this topic did not focused on the occupational health component, focusing especially on occupational security. We affirm this because both the national legislation in force and the OHSAS 18001 standard deal with both aspects. Starting from this observation, the authors propose a model of occupational health program intended especially to help companies reduce the costs of absenteeism on case of illness and which could also positively change employee perceptions over the employer and why not in this context could lead even to thereof higher performance.

*Keywords:* occupational health; modeling; therapies; improving the health of employees

---

### 1. Introduction

Concern for employee health is often a neglected process, in some ways, by employers (we are talking, especially, about employers in Romania). It is not explicitly specified in the legislation that the employer should also consider this aspect. An example would be Article 27 of Section 4 named Internal Prevention and Protection Services under Law 319/2006 specifying: "The Internal Prevention and Protection Service may also provide for the supervision of the health of workers if they have staff with professional and appropriate material means, according to the law ". Another example could be that although in this law the word health or its variants is mentioned not less than 339 times and only about 1% this word occurs independently of the expression health and safety at work.

Throughout the experience in the field, we have heard, often, that health is the responsibility of the physician, in way of the health of the employee, is the responsibility of the occupational medicine doctor. So we (persons/employees/employers) have nothing to do and we should not get involved. It's not like this...?

Following a more detailed analysis of this phenomenon, we have concluded that the above-mentioned process, namely the concern for employees' health if brought to the spotlight, may become a factor, not negligible, of increasing the profit of an organization. We refer here in particular to the possibility of reducing the costs of paying sick leave for the employer (the first five days of temporary incapacity to work under Law No. 399 of 30 October 2006 for the approval of Government Emergency Ordinance No. 158/2005 on leave and health insurance benefits). Of course, we must also take into consideration the problems generated in the organizations by sickness absenteeism.

Taking these issues into account, we generated a model of occupational health program in order to facilitate the cutting down of the cost of absenteeism linked by the sickness in companies.

### 2. Conceptual modeling of an occupational health program

#### 2.1. General aspects

At present, organizations are struggling for survival and supremacy on the market. The winners of this struggle were and are the organizations that have managed to create a discriminator in their sector of activity. Thus, successful models have emerged as sufficiently flexible and adaptable to market conditions, according to Zerbes, 2017. Marcu, 2002 defines the model as an ideal or material system by means of which the properties and transformations can be studied by analogy or by mathematical calculation to another more complex system and / or process. In other words, a model is a simplified representation of a process or system according to the definition of the "Iorgu Iordan - Alexandru Rosetti" Institute of Linguistics within the Romanian Academy, 2009.

---

\* \* Corresponding author. Tel.: +40-752-114-375; fax: +40-269-217-887.

E-mail address: mihai.zerbes@ulbsibiu.ro.



The objective of a model is to predict with a certain degree of accuracy the behavior of a system / process. The accuracy of a model depends, among other things, on: the accuracy with which everyone wants to know the system / process running, the time available, the necessary money, the accuracy of the input data, the calculation facilities, etc. Lobont said in 2002.

Taking into account all this and their experience, the authors of this paper have developed a model of health program meant to become, as we have already said, a discriminant for the organizations that will use it. The model, generically named IAP-IAP, is briefly presented below.

## 2.2. Brief presentation of the proposed model

The acronym IAP-IAP derives from the original model developed by the authors shown in Figure 1:

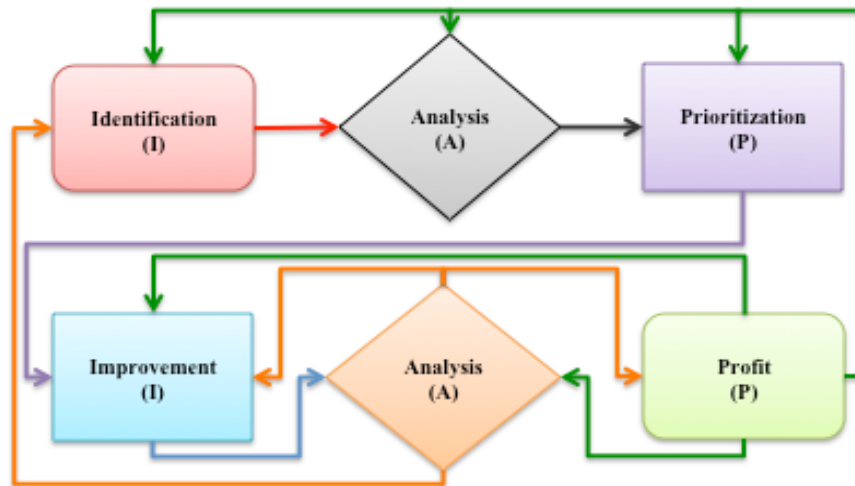


Fig. 1. The general model

Starting from the general model, we have developed a model specific to occupational health (OH) as follows:

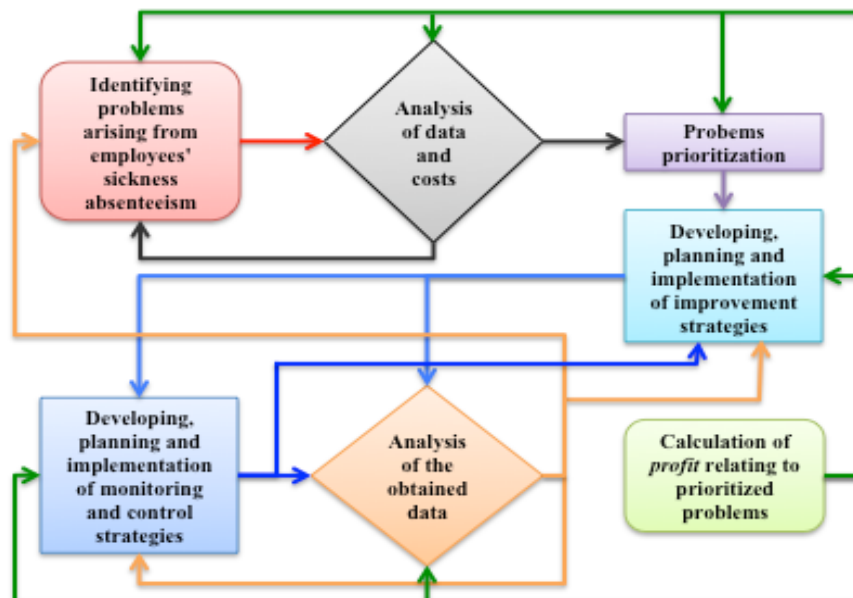


Fig. 2. OH specific model

## 2.3. Detailed model presentation

For a better understanding of the model and its mode of operation, we present the model in 3 distinct but complementary forms: graphic, tabular and mathematical. The graphic model is shown in Figure 3 as a flow diagram and aims to highlight the steps in which the modeling process takes place and the relationships between them.

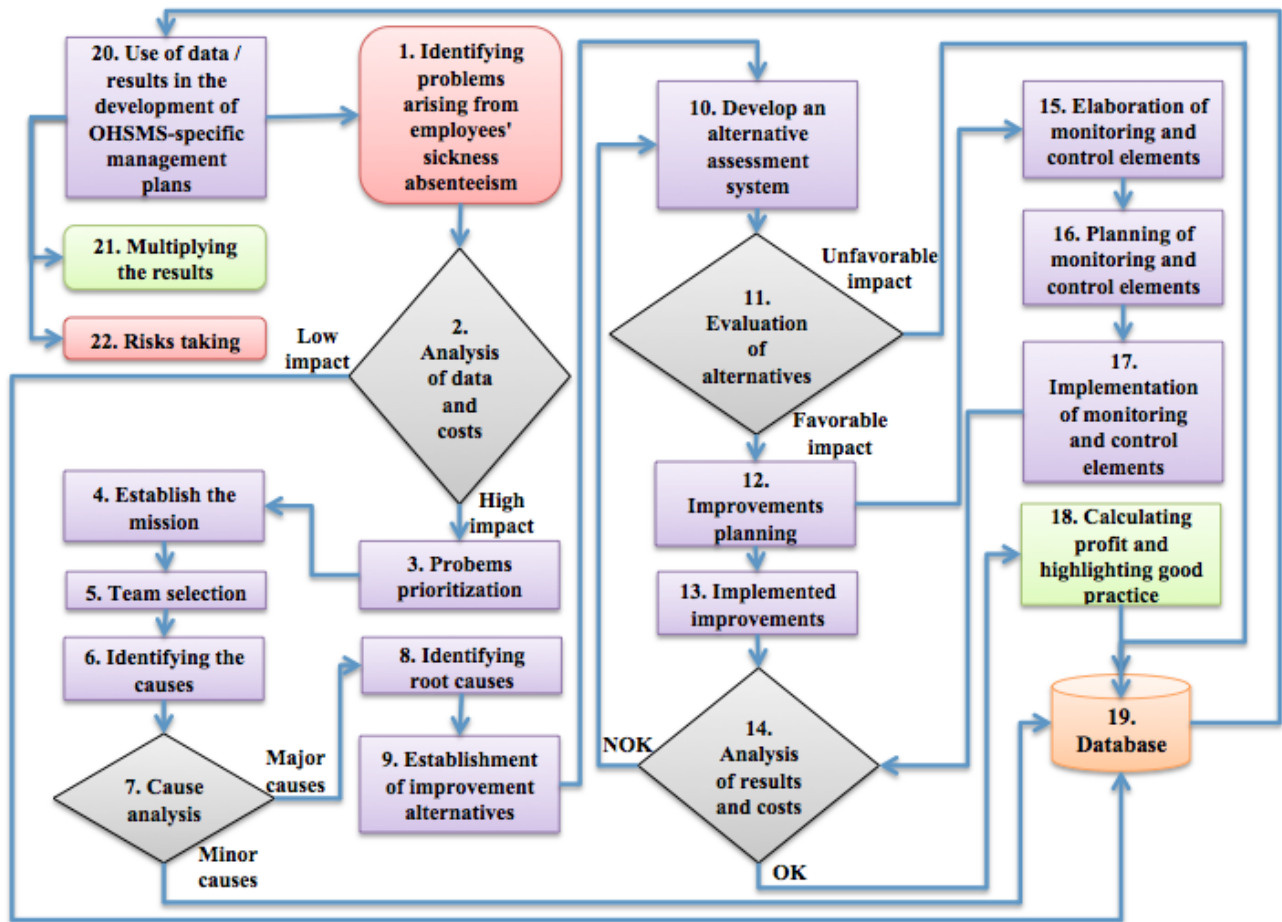


Fig. 3. Steps of the modeled process

Because the lack of space (due to the drafting restrictions) we only present the way of building the tabular model (table 1). We also took into account the fact that the specialists from the organizations that will adopt it can personalize the tabular model.

Table 1. An example of a table

Activities	Recommended methods, techniques and tools	Aim	Performance indicator	Weighting coefficient	Risk coefficient
A1	A	A1.1	P1.1.1	W1.1.1	R1
	B		.	.	
	C		.	.	
	.	A1.2			
	.	.			
	X	.			
		A1.n			
.	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.
A22					R22

Mathematically expressed (Zerbes, 2017) the tabular model is presented as:

$$M_{OHP} = (\sum_{i=1}^{22} A_i) R_i \quad (1)$$

in which:

$$\sum_{i=1}^{22} A_i = \sum_{j=1}^m P_j W_j + \dots + \sum_{y=1}^x P_y W_y \quad (2)$$

therefore:



$$M_{OHP} = (\sum_{j=1}^m P_j W_j) R_1 + \dots + (\sum_{y=1}^x P_y W_y) R_{22} \quad (3)$$

where:

$M_{OHP}$  – OH program model  
 $P_{j...y}$  – performance indicator  
 $W_{j...y}$  – weighting coefficient  
 $R_i$  – risk coefficient

It should be noted that  $R_i$  - risk factors might vary from one organization to another depending on several factors such as experience, time priorities, organizational politics, etc.

#### 2.4. Discussion

The conceptual model proposed by us has as its starting point the classical diagram of the process model presented in Figure 4 (Zerbes & Budău, 2005). Thus, it has defined the inputs, outputs, control elements and the mechanisms necessary for the functioning performance of the proposed model.

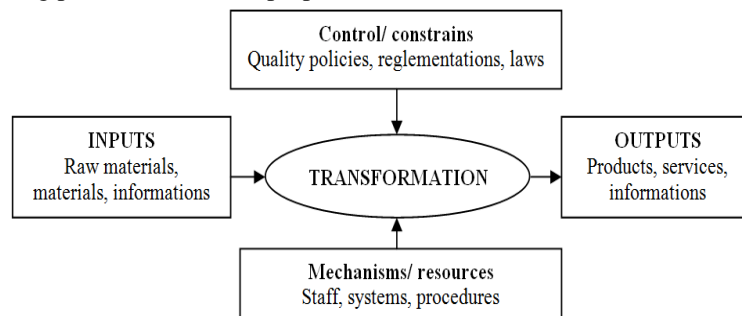


Fig. 4. The classical diagram of the process model

In order to facilitate the processes of regulating and implementing planned improvements, one can use the representation mode called tabular flow diagram (Table 2) to highlight the inputs, outputs and responsibilities associated with each activity in the process. For their establishment, organizations will appeal to internal and external experts, especially for consultants in the field. As we can see, we recommend that you determine the responsibilities to use the Deming cycle (PDCA).

Table 2. The tabular flow diagram

Inputs	Activities	Outputs	Responsibilities (human resources)				
			Plan	Do	Check	Act	Reporting
Resurse: • Material • Financiare • Informationale	Flow chart from figure 3	Rezultate:					
		• Tengibile (rapoarte, procese verbale, instructiuni, dispositive, echipamente etc.) • Intangibile (cunostinte, experienta etc.)	Cine planifica activitatea?	Cine implementeaza activitatea?	Cine monitorizeaza si controleaza activitatea?	Cine decide luarea masurilor de imbunatatire?	Cine raporteaza catre top management?

Regarding the documentation of the planning and implementation activities both of the improvements and of the control elements, we recommend that the organizations use the structure specific to the project management. In this respect, due to the fact that we are actually talking about a project to improve the health of employees, we will consider at least of the following aspects:

- Project title;
- Period of deployment;
- Possible funding sources;
- The project team (for each function involved, the job description will be drafted and a work contract if the team / function comes from the outside of the organization or an annex to them if the team / function is from the inside);
- Partners / collaborators (if it's applicable);
- Target group;
- Project justification (describe the situation of the target group before implementing the project, describe the causes and effects of the identified problem);

- Project beneficiaries (mention the direct and indirect beneficiaries of the project);
- SWOT analysis of the ability of the organization and / or team to solve the identified problem;
- The purpose of the project;
- The objectives of the project (the ways to reach the goal);
- Project results;
- The activities / work breakdown structure (details of the project activities according to the established objectives, pointing for each activity the sub-activities, the resources necessary for their implementation and the related duration);
- Budget (make budget by grouping costs by spending categories - human resource expenditures and material resource expenses);
- Implementation chart (Gantt diagram);
- Daily schedule and description of the activity / function;
- Daily schedule and description / target group (target group), etc.

We mention the fact that the stage of the occupational health program dedicated to the employee will consist in the implementation of integrative therapies and will be complementary to the medical services provided by the doctors of occupational medicine. Consequently, depending on the affections identified at the targeted employees, the program will include specific elements:

- allopathic medicine such as:
  - specialized medical check-ups (eg: cardiovascular, musculoskeletal, digestive system, etc.);
  - investigations;
  - medical tests;
- alternative medicine from practices:
  - Ayurveda;
  - traditional Chinese medicine;
  - homeopathy;
  - acupuncture, etc.
- complementary therapies such as:
  - physical therapy;
  - osteopathy;
  - massage;
  - reflexology;
  - presopuncture;
  - Bowen technique;
  - dietotherapy;
  - phytotherapy;
  - apitherapy;
  - hydrotherapy;
  - hirudotherapy;
  - psychotherapy;
  - sacrotherapy;
  - bioenergotherapy, etc.;
- personal development programs on topics such as:
  - nutrition education;
  - health education;
  - healthy lifestyle;
  - personal hygiene;
  - teamwork and teambuilding;
  - time management;
  - stress management;
  - physical education;
  - maintenance gyms;
  - yoga;
  - aikido;
  - tai chi;
  - qigong;
  - the music;
  - dance;
  - meditative painting;
  - eurythmia etc.

### 3. Conclusion

In conclusion, we believe in the efficiency of such programs. In the article *Occupational health programs and workplace absenteeism*, the authors (the same authors as the present paper) present such a program successfully implemented, in a company in Sibiu in the field of software consultancy.

We anticipate that such programs can increase the quality of life by improving service relationships with beneficial effects on all employees by increasing the level of trust in the team and management. Thus, the employer also will win by reducing especially staff fluctuations and increasing the company's profit. It is worth mentioning that without the direct involvement of top management in the organization such programs have no chance of success. However, the employer must first understand the benefits of using such a program and find out the strategies of awareness and motivation of employees who would participate in such a program.

Also, we must not forget the social benefits of such a program, first of all by improving the health status of the community they belong to employees. In this context, we recommend family involvement to increase motivation and ensure long-term compliance.

Finally, in the context of those presented in the paper, is the question from the introduction: Who is responsible for my health (as an individual / as an employee)?

### References

- Legea 319, *LEGE nr. 319 din 14 iulie 2006 (\*actualizată\*) a securității și sănătății în muncă*, Emitent: Parlamentul României, Publicat în: Monitorul Oficial nr. 646 din 26 iulie 2006, Data intrării în vigoare : 1 octombrie 2006, Forma actualizată valabilă la data de : 6 martie 2017, (2006)
- Legea 399, *LEGE nr. 399 din 30 octombrie 2006 pentru aprobarea Ordonanței de urgență a Guvernului nr. 158/2005 privind concediile și indemnizațiile de asigurări sociale de sănătate*, Emitent: Parlamentul României, Publicat în: Monitorul Oficial nr. 901 din 6 noiembrie 2006, (2006).
- Ordin 15/1311, *ORDIN nr. 15/1.311/2018 pentru aprobarea Normelor de aplicare a prevederilor Ordonanței de urgență a Guvernului nr. 158/2005 privind concediile și indemnizațiile de asigurări sociale de sănătate*, Emitent: Ministerul Sănătății Nr. 15 din 5 ianuarie 2018, Casa Națională de Asigurări de Sănătate Nr. 1.311 din 29 decembrie 2017, Publicat în: Monitorul Oficial nr. 31 din 12 ianuarie 2018, Data intrării în vigoare: 12 ianuarie 2018 (2018)
- Zerbes, M. V., *Planificarea și proiectarea avansată a proceselor și produselor în industria auto*, Editura Techno Media S.R.L. din Sibiu, ISBN 978-606-616-288-3, (2017).
- Marcu, F., *Marele dicționar de neologisme*, Editura Saeculum, București, (2002).
- Academia Română, Institutul de Lingvistică „Iorgu Iordan - Alexandru Rosetti”, *DEX '09: Dicționarul explicativ al limbii române*, ediția a II-a revăzută și adăugită, Editura Univers Enciclopedic, (2009).
- Lobonț, L., Referatul 1: *Modelarea și Managementul Proceselor*, Facultatea de Inginerie din Universitatea "Lucian Blaga" din Sibiu, coordonator științific Prof. univ. dr. ing. Oprean Constantin, (2002).
- Zerbes, M. V., Budău, G., *Cercetări privind descrierea proceselor unui sistem de management al calității într-o organizație cu profil de prelucrarea lemnului*, Buletinul Conferinței Naționale Știința și Ingineria Lemnului în Mileniul III, Ediția a VI-a, Universitatea "TRANSILVANIA" din Brașov, 4-6 noiembrie, (2005).

## Occupational health programs and workplace absenteeism

Zerbes Mihai-Victor<sup>a</sup>, Cioca Lucian-Ionel<sup>a</sup>, Neamu Vasilica-Silvia\*

<sup>a</sup> “Lucian Blaga” University of Sibiu, 10, Victoriei Bd, Sibiu, 550024, România

---

### Abstract

Currently, at national level, there is no direct concern for occupational health. Moreover, in industrial organizations and not only the phrase "security and occupational health" is not yet well understood and used to its true value. In this article the authors show a facet of this component, namely how occupational health programs can influence the process of improving absenteeism at work. In this regard, the authors present a case study related to employees of a software consultancy company suffering from musculoskeletal disorders.

*Keywords: occupational health; workplace absenteeism; musculoskeletal disorders*

---

### 1. Introduction

#### 1.1. General aspects

Productivity has always raised the same challenges / challenges for both multinational and national corporations as well as for small businesses. These challenges include the reduction of absenteeism, the increase in profit, the actions to be taken in relation to employees who are no longer performing, etc.

Following Corbett's 2003 study on productivity and profitability, it was concluded that organizations could be far more productive than they are. Of the CEOs who participated in this study, 53% said that organizations do not reach their productive potential. With this statement, 52% of the employees also agreed. Among the factors contributing to the deficit in organizations' profitability, specialized studies indicated that:

- 66% -71% of loss of profitability is due to physical and / or emotional health problems, stress, burnout of employees;
- 42% -59% of the loss of profitability is due to poor management strategies;
- 39% to 48% of the loss of profitability is due to the lack of effective training programs.

If past research and organizational policies were focused on profitability factors and losses, lack of effective marketing strategies, and lack of technology, the latest research provides information on the "hidden" causes of profitability losses, Davis & al.

Among the most important hidden causes are the fragile health statuses of employees. This state has the greatest negative impact on employee productivity and organization results. Employee health has effects on the performance from the workplace. These effects can be direct, such as absenteeism due to the impossibility of coming to work, or indirectly, the presenteeism of (Lowe, 2004), ie the unproductive state of the employee present at the workplace which cannot have maximum performance due to of disturbing factors such as: negative emotional states, stress, illness or general uncomfortable state due to headaches, stomach, back, etc. Due to absenteeism and presenteeism, companies face a lot of unproductive labor, ie working days lost due to presenteeism or absenteeism classes, and the costs of unproductive labor are often enormous. Stewart & Stewart's studies in 2003 found that 86% of all non-productive work time is due to strictly presenteeism work, a factor that increases the cost of organizations due to employees' remuneration at that time, as well as the increase in error rates in the workload thing. Thus, cumulative presenteeism hours with absenteeism generate the unproductive work time. To avoid unproductive work, one of the imperative conditions is to maintain and improve the health of employees. As a result, companies will benefit from sustainable work performance and increased overall profit.

---

\* Corresponding author. Tel.: +40-752-114-375; fax: +40-269-217-887.

E-mail address: mihai.zerbes@ulbsibiu.ro.

### *1.2. Aspects regarding the affections targeted in the case study*

In this research, we focused on musculoskeletal disorders (MSD) which represents an group of painful disorders of the muscles, tendons, joints and nerves. All parts of the body may be affected, but the upper and rear limbs being the most exposed. MSD occurs due to movements such as bending, straightening, grip, holding, twisting, tightening, crushing, kneading and stretching. These regular movements are not necessarily harmful in the course of daily activities. What makes them dangerous during work is repetitiveness, often forced, and especially, the speed of movements and the lack of rest breaks between them. Heat, cold and vibration also contribute to the appearance of MSD. In Europe, musculoskeletal disorders are the most common work-related health problems. A quarter of EU workers accuse back pain and nearly a quarter complain of muscle pain according to a study by the European Foundation for the Improvement of Living and Working Conditions in 2007. All musculoskeletal disorders interrupt work, reduce productivity and generate the absenteeism from medical reasons and of course chronic professional incapacity. MSD is a serious concern: it affects workers' health and increases the economic and social costs of businesses and European countries, according to the European Agency for Safety and Health at Work 2007. A previous report by the Agency mentions that some studies have estimated the cost of MSDs affecting upper limbs somewhere between 0.5% and 2% of Gross Domestic Product (GDP). MSD is still a significant and significant health problem. At European level, musculoskeletal disorders are the most common occupational diseases. In 2005, they accounted for about 39% of all occupational diseases according to the mandatory register. According to the latest figures provided by the European Working Conditions Survey, in the EU, back pain seems to be the most important work-related disorder, while in the new Member States, back pain is the second most exhausted. This is also one of the reasons for choosing our research topic, focusing on the spine specific affections, namely on kyphosis, lordosis and scoliosis.

The European Agency for Safety and Health at Work analyzed, for the first time, more careful, work-related musculoskeletal disorders in the 2000 reports, according to Buckle & Devereux, and Op de Beek & Hermanns, 1999.

### *1.3. Brief description of the organization where the research was conducted*

For reasons of confidentiality we cannot present the name of the organization presented in the case study. It is a multinational company with more than 2500 employees at European level, the Sibiu branch with approximately 450 employees. The typical form of work in the company is office work. Thus, regardless of the job, each employee spends most of his working time at the office. For this reason, the company is equipped with ergonomic desks and chairs that support employees' health. Also, a system of occupational health and safety management is implemented at both company and branch level in Sibiu. However, MSDs is not missing from the company / subsidiary. The main causes of MSD identified in our research are briefly presented in Figure 1. We present in this paper only the results of the recovery program followed by employees from the chosen sample.

## **2. Case study**

### *2.1. Methodology*

The study was conducted according to the occupational health program model presented in the work *Developing a Model of Occupational Health Program in SIMPRO 2018*. Due to lack of space, we will briefly present only a part of the 22 steps of the model. Thus, in the last management analysis carried out within the organization targeted in this case study, the issue of employee absenteeism was also discussed. Following this analysis, the top management of the company decided to turn to external experts (the authors of this paper) to help them improve the costs regarding of absenteeism. Experts analyzed the documentation and formed a team of 7 members: 3 experts, 2 employees of the management company, 1 physical therapist and a fitness trainer. The team has developed the improvement program following the project management specific steps. The program is briefly presented below.

Duration of the program: 05.02.2018- 31.06.2019. Consequently, in this case study, will present only a preliminary phase, namely the results obtained after 2.5 months from implementation.

### *2.2. Participants*

The sample chosen for the study included 20 of the 450 employees of the company who accumulated most of the sick leave due to the three types of MSD during the year 2017. The selection of the sample was made according to the following working procedure:

- the analysis of the statistical data on medical leave in 2017, which showed that the largest weight is due to MSD (Figure 2);
- analyzing data on employees who have absent on a sickness case basis due to MSD, which found that 50% of the 40 identified employees are responsible for 80% of the number of days off. Thus, of the 1102 days of sick leave (SL), 881 days were related to the 20 employees (table 1).

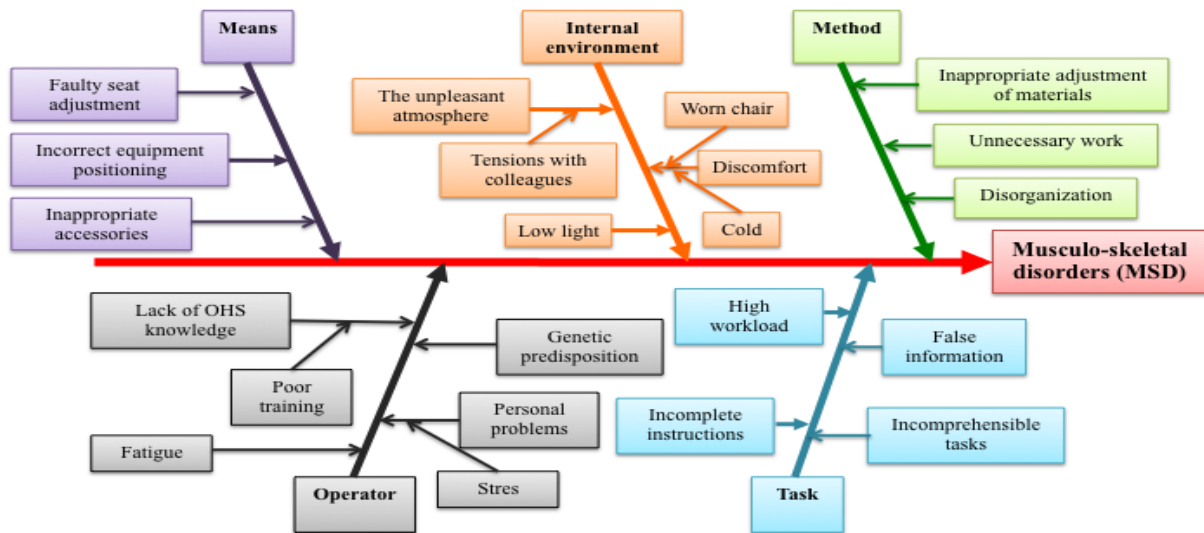


Fig. 1. The main causes of MSD

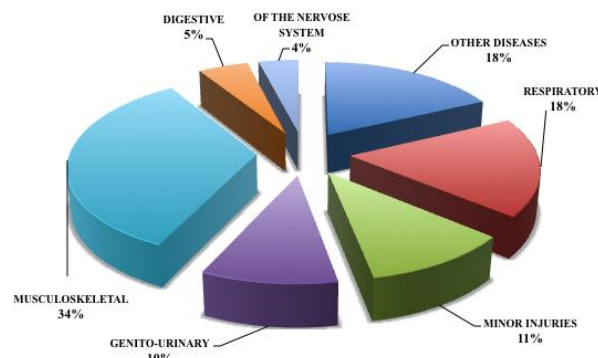


Fig. 2. Weight of sickness leave days

Table 1. Employees with MSD

Number of employees with MSD	% of total employees	Number of SL cases	Number of SL days	Related cost
40	8.89	160	1102	35,744 euro

### 2.3. Data collection

In 2014, Băbuț & Moraru says that workplace / workstation analysis is the fundamental element for identifying risk factors for preventing and protecting disease and establishing appropriate prevention and protection measures. From this perspective, the authors of this research collected the input data needed to improve the process in four ways:

- analysis of the documents from the doctor of occupational medicine;
- analysis of statistical data on medical leave in 2017;
- applying a questionnaire to identify employees' lifestyles;
- analysis of accident and occupational disease risk assessment files.

### 2.4. Aim and objectives of the program

The aim of the project is to reduce the number of medical leave for musculoskeletal disorders to a maximum of 10% of the total number of medical leave within 12 months of the implementation of the project.

The objectives are presented in Table 2 alongside their performance indicators, indicators that have been developed to facilitate the monitoring and control of program implementation.

Table 2. The objectives of program

Objectives	Performance indicators
A. Identifying the current health status of employees within 5 working days of starting the project	$Ia = Te_a / Tpa \leq 1$
B. Planning for specialist health check for identified employees within 15 business days of project start	$Ib = Te_b / Tpb \leq 1$
C. Implemented specialist health check for identified workers within 25 business days of starting the project	$Ic = Te_c / Tpc \leq 1$
D. Making a questionnaire on a healthy lifestyle within 30 days of starting the project	$Id = Te_d / Tpd \leq 1$
E. Applying the questionnaire within 35 working days of the start of the project	$Ie = Te_e / Tpe \leq 1$
F. Analysis of data collected through the questionnaire and the results of the medical check-up within 40 working days of the start of the project	$If = Te_f / Tpf \leq 1$
G. Subcontracting a fitness station for setting up and running a sports program within 45 working days of the start of the project	$Ig = Te_g / Tpg \leq 1$
H. Develop a program to improve musculoskeletal disorders within 50 working days of project start	$Ih = Te_h / Tph \leq 1$
I. Implementation of the musculoskeletal improvement program in 140 working days since the start of the project	$Ii = Te_i / Tpi \leq 1$
J. Developing a fitness for maintenance program within 145 business days from the start of the project	$Ij = Te_j / Tpj \leq 1$
K. Implementation of the fitness for maintenance program within 240 business days from the start of the project	$Ik = Te_k / Tpk \leq 1$
L. Monitoring and control of employees' physical conditions throughout the project	$Il = Te_l / Tpl \leq 1$
M. Analysis of the data obtained from the monitoring and control of the employees' physical condition throughout the project	$Im = Te_m / Tpm \leq 1$
N. Drawing up the project documentation in the last 9 working days of the project	$In = Te_n / Tpn \leq 1$

where:

- I - Performance Indicator
- Te - Time achieved
- Tp - Planned time

### 2.5. Activities specific to the MSDs improvement process

The results obtained from the analysis and interpretation of the collected data is summarized in Figure 3.

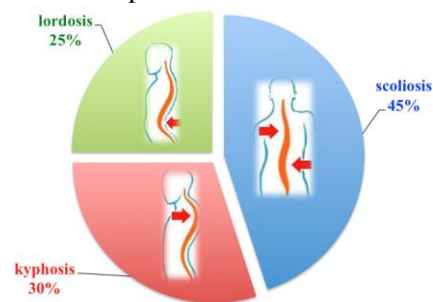


Fig. 2. Weight of sickness leave days

For the relief of these MSDs, three different exercise programs were developed, depending on the needs of each category of MSDs. The therapist recommends the frequency of treatment and takes into account, in particular, the severity of the condition. These programs will be supported for 18 weeks at a pre-booked fitness room (Table 3).

Table 3. Three different exercise programs

MSDs	Scoliosis	Kyphosis	Lordosis
<b>Corrective exercises</b>			
<b>Maintenance exercises</b>			

After supporting MSDs by employees for 18 weeks, they will follow maintenance programs for 19 weeks. Specialist personnel will personalize maintenance programs as soon as the employees complete the improvement step. The maintenance program will be performed 2-4 times a week, aiming at the formation of a reflex to correct the wrong attitude of the body.





Table 4. Costs and benefits of the implemented occupational health program

Benefits	Costs
<ul style="list-style-type: none"> <li>+20,234 euros that will no longer be paid for medical leave related to musculoskeletal disorders in the first year, this amount accounting for 57% of the cost of current medical leave</li> <li>In the second year, at least 90% of the diseases being healed, at least 25,851 euros will be saved from the cost of the initial medical leave, this amount accounting for 72% of the current medical leave costs</li> <li>Increasing employee productivity and company profit</li> </ul>	<ul style="list-style-type: none"> <li>Investments / sponsorships to implement the Occupational Health Program: approximately 17,147 euro</li> <li>Working time of the team</li> </ul>

Implementing such a program is undoubtedly one of the best decisions an organization can take, a decision that has considerable financial and human implications. Here are some advantages and disadvantages for implementing such a program:

Table 5. Advantages and disadvantages of occupational health programs

Benefits	Disadvantages
<ul style="list-style-type: none"> <li>Increasing employee productivity</li> <li>Improving the quality of employees' lives employee awareness of workplace risks and the importance of occupational health</li> <li>Stimulate employees for a healthy lifestyle</li> <li>Increase the company's credibility</li> <li>Increasing employee satisfaction at work</li> <li>Improving the health of employees</li> <li>Developing social relationships between colleagues within the company</li> </ul>	<ul style="list-style-type: none"> <li>Limited funds</li> <li>Not all employees are willing to participate</li> <li>The results are limited by the short time Need for staff availability</li> <li>Constant motivation of employees for engagement</li> </ul>

The success of an occupational health program depends primarily on the leadership of company and its involvement, especially the degree to which it is willing to engage in implementing and supporting the program, a factor without which any program would be successful. However, employee teams that make this change possible also influence success, and teamwork stimulates the prolongation of the program after the study. Thus, the motivation of both the management and the project team is crucial in the success of the program.

This program is intended to be practical proof of the potential that these occupational health programs can have, motivating not only management but also whole teams of employees to implement as many occupational health programs as possible to increase both employee productivity and profit company, and to take advantage of all the personal and professional benefits that accompany these profitable projects.

## References

- Corbett, D., *Why Focus on the Healthy Workplace? Building the Case for Healthy Workplace*, National Quality Institute, (2003).
- Davis K., Collins S., R., & al., "Health and Productivity Among U.S. Workers", Commonwealth Fund, [http://www.commonwealthfund.org/usr\\_doc/856\\_Davis\\_hlt\\_productivity\\_USworkers.pdf](http://www.commonwealthfund.org/usr_doc/856_Davis_hlt_productivity_USworkers.pdf) accesat în: 22.02.2018
- Lowe, G., Healthy Workplace Strategies, Canadian Policy Research Network, <http://www.longwoods.com/view.php?id=&aid=16975&cat=110> accesat în 23.02.2018, (2004).
- Stewart, W., F. & al., *Cost Of Lost Productive Work Time Among US Workers*, JAMA, pag. 35-44, (2003).
- Fundația Europeană pentru Îmbunătățirea Condițiilor de Viață și de Muncă, *Al patrulea studiu privind condițiile de muncă europene*, <http://www.eurofound.eu.int/ewco/surveys/EWCS2005/index.htm> accesat în: 20.02.2018, (2007)
- Agenția Europeană pentru Securitate și Sănătate în Muncă, *Raport tematic privind AMS*, (2007).
- Buckle P. & Devereux J., *Work-related upper limb musculoskeletal disorders*, Magazine of the European Agency for Safety and Health at Work, EU-OSHA, Bilbao, <http://osha.europa.eu/en/publications/reports/201> accesat în: 20.02.2018, (1999).
- Op de Beek, R. & Hermanns, V., *Research on work-related low back disorders*. Magazine of the European Agency for Safety and Health at Work, EU-OSHA, Bilbao, <http://osha.europa.eu/en/publications/reports/204/view> accesat în: 20.02.2018, (1999).
- OG 158, *Ordonanță de Urgență nr. 158 din 17 noiembrie 2005 privind concediile și indemnizațiile de asigurări sociale de sănătate*, Emitent: Guvernul, publicat în: Monitorul Oficial nr. 1074 din 29 noiembrie 2005, data intrării în vigoare: 19 Decembrie 2005, (2005).
- Băbuș, G.B., Moraru, R.I., *Legislative and methodological framework for integrating the own occupational safety and health instructions in professional risk management of an organization*, Proceedings of the 20th International Conference „The Knowledge-Based Organization”, „Nicolae Bălcescu” Land Forces Academy Publishing House, Vol. 2: Economic, Social and Administrative Approaches to the Knowledge Based Organization, Section 5: Economic, (2014).

## A propose approach for continuous improvement using ergonomics and quality management knowledge and methodologies

Bianca Cirjaliu<sup>a</sup>, Anca Mocan<sup>a</sup>, Maria-Elena Boatca<sup>a</sup>, Anca Draghici<sup>a</sup> \*

*<sup>a</sup>Politehnica University of Timisoara, Pta Victoriei 2, Timisoara 300222, Romania*

---

### Abstract

In the last years, quality management knowledge and methodologies support companies' continuous improvement strategies. In this context, the most popular organizational model is Lean Six Sigma and its practical exploitation is based on the structured approach DMAIC (Define, Measure, Analyse, Improve and Control) cycle. In each phase a set of tools and methodologies are applied, as brainstorming, cause-and-effect diagram and control charts. In the context of the present research Lean Six Sigma and DMAIC are integrated with Ergonomics approach (principles and knowledge) in order to create a synergistic effect aiming to support the continuous improvement processes by consider a holistic view of the human side of the production systems. Thus, the article will present the fundamentals of the proposed methodological framework that has been designed and which coherently applies the principles of both filed of science (ergonomics and quality management) and simultaneously ensuring gains in productivity and in workplace well-being.

*Keywords:* Ergonomics, Quality management, Lean Six Sigma, DMAIC cycle, holistic framework

---

### 1. Introduction

Continuous improvement process is embracing by companies to achieve operational and service excellence. This approach part of the performance management domain of organizations' interest because of the increase in competition and globalization. Therefore, companies need to adjust their strategic management and continuously improve performance in all areas (e.g., operations, organization) keeping up with strong competition on the markets they operate (Melton, 2015; Nunes, 2015; Cirjaliu and Draghici, 2016).

Lean Management and Six Sigma philosophies have been considered as the most adequate initiatives for the continuous improvement of organizations: Lean approach focuses on eliminating the sources of waste, aiming a continuous process flow (focus on operation management and business process management), while Six Sigma focuses on reducing the process variability (focus on quality management) (Nunes, 2015). These are complementary approaches and companies establish programs designed as Lean Six Sigma (Cirjaliu and Draghici, 2016). Therefore, Lean Six Sigma (LSS) concept represents a business philosophy and strategy to drive continuous improvement of production processes to reach higher customer satisfaction simultaneously with high profit rates; it supports good productive performance, based on the reduction of waste, variability and costs of production (Devane, 2004; Taghizadegan, 2010).

In the last years, companies that have implemented the LSS have started to search for other knowledge sources of improvements because operation managers sometime complain on employees working stress affecting productivity because of the strict duration and high quality of their demanded tasks. In addition, the achievement of the work of (Luz Peralta et al., 2016) was noted that often the ergonomics and safety are the background, as companies seek productivity and profit.

In this context, the present research proposes that ergonomic approach to be integrated simultaneously with LSS to diminish work stress but increasing the work productivity (eliminate the delays and avoid the stagnation of manufacturing processes) as suggested by the studies of (Nunes, 2015; Cirjaliu and Draghici, 2016). Both Ergonomics and LSS are system-oriented approaches. However, frequently ergonomic approach is neglected by managers and often is associated with Occupational Safety and Health (OSH) in the context of the risk management approach.

---

\* Corresponding author. Tel.: +40-256-403610; fax: +40-256-403610.  
E-mail address: anca.draghici@upt.ro.

In the content of the present research there will be presented the proposed approach of integrating ergonomics principles and LSS (and not neglected risk management and OHS). This will assure the preliminary conditions for the creation of a decision-making support that will help operation management in the continuous improvement processes tailored to their specific needs (eliminating employees stress and increase work productivity).

The paper structure consists of: (1) literature review for the interest issues regarding LSS and ergonomics; (2) the description of the proposed approach of an ergonomics and LSS integration, by pointed the role of knowledge management to create the expected decision-making support. In the end some conclusions and future researches will be presented.

## **2. Literature review**

### *2.1. Ergonomics – premise for the integration with LSS*

Ergonomics is the interdisciplinary science that focuses on systems where the interaction between people and their environment occur. Ergonomics is a human oriented science focuses on the optimization of human energy consumption in the professional activities and thus, to well-being but simultaneously with maintaining overall performance (in terms of productivity) (IEA, 2018). Therefore, ergonomics can be characterized by (1) having a system approach; (2) being design driven and (3) focuses on performance and well-being (Dul et al., 2012; Richardson et al., 2017).

The literature review in the field of ergonomics has underlined that there is still a great knowledge potential that has been under-used, being one of the reasons that managers neglect ergonomics value. “Ergonomics is mainly associated with the workers well-being, being most often housed within the Occupational Safety and Health (OSH) department, therefore managers tend to inadvertently restrict its scope of intervention to OSH hazards, instead of benefiting from its help to organizational effectiveness, business performance or costs” (Nunes, 2012).

Nowadays, researchers and practitioners have recognized in disparate studies (in different industrial domains) the value of ergonomics knowledge that could support also, health and safety approaches, occupational risk mitigation. Ergonomics can add value to a company’ business strategy to reach the ultimate business goal of profit, or intermediate business goals related to profit drivers like cost minimization, productivity, quality, delivery reliability, responsiveness to customer demands, or flexibility (Draghici and Draghici, 2000; Jul and Neumann, 2009; Nunes, 2015; 2000, Cirjaliu and Draghici, 2016; Draghici et al., 2017). Therefore, it is necessary a paradigm shift, which requires a re-positioning from a primary health ergonomics approach to a more business-oriented ergonomics approach (Jul et al., 2012).

The integration of ergonomics principles in LSS matches this new paradigm.

### *2.2. Lean Six Sigma relevant aspects – premise for the integration with ergonomics*

Lean concept was first introduced to interpret Toyota’s new production system that does away with mass production, to describe the highly efficient production system which uses less of every resource to produce the same number of products with competitive quality and cost (Behrouzi and Wong, 2011).

Lean Six Sigma results from the combination of two different but complementary management philosophies: Lean Management and Six Sigma (Albliwi and Antony, 2011). Lean Management is a production philosophy that evolved from the Toyota Production System (TPS) and appeared after the 2nd World War. Its focus on supporting companies achieving on time the delivery of the right product quality and quantity to satisfy customer demand. It is based on the following five principles (Cirjaliu and Draghici, 2016):

- Specify Value – it is necessary to specify what adds value from the end customer’s perspective, so that all the non-value activities can be identified and removed; in fact, for most production processes only a small part of the total production time and effort adds value for the end customer;
- Identify the Value stream – identify all activities that don’t aggregate any value to the final product;
- Create Flow - promote continuous flow in the process by eliminating wastes;
- Customer Pull – respond to customer demand; produce what customers want at the right time;
- Pursue Perfection – continually remove wastes, striving for a perfect process.

These five principles strongly underline that Lean Management focuses on the elimination of the non-value-added activities or wastes. From the practical perspective, there are eight different types of wastes: transportation, excessive inventory, unnecessary movements, over production, over processing, waiting time, quality/defects and intellect underuse (Fullerton et al., 2014).

From the praxiological point of view, to support the Lean Management philosophy implementation in reducing lead and set up times, inventories, equipment downtime, scrap, rework and other wastes there are many tools and techniques. Some examples are: 5S, Kaizen, Value Stream Mapping, Kanban and SMED. The Six Sigma methodology is a management program developed by Motorola Company, in the 80s, in response to an increase of the international

market competitiveness created by Japanese companies. To cope with this situation, Motorola felt the need to improve the process quality, due to an excessive amount of defective production parts (Salah et al., 2010; Cherrafi et al., 2016). Six Sigma seeks to achieve high levels of quality and low levels of variability, by detecting and removing defects causes (Salah et al., 2010). Because of this philosophy, the waste of organizations decreases, and the production variability is reduced as well improving production control and forecasts (Vinodh et al., 2011; Nunes, 2015). Its application is based on DMAIC (Define – Measure – Analyze - Improve - Control) cycle. From the practical perspective, in each DMAIC phase are used different methodologies and tools (e.g., brainstorming, Cause-and-effect analysis, control charts etc.).

The objective of the LSS implementation is to improve performance of production processes by reducing waste, variability, costs and satisfying customers (Jul and Neumann, 2009; Slah et al., 2010). Based on the DMAIC approach, LSS is a solution for problem solving that integrate, in a synergetic manner, tools from both philosophies. Furthermore, the simultaneously use of lean management and six sigma creates a more effective way to identify root causes of problems rather than focusing on the processes where the problems appear (Slah et al., 2010; Nunes, 2015).

### 3. The proposed framework of integrating ergonomics and LSS

The literature review has underlined different aspects related to psychological risks (and stress) that affect employees when their tasks are developed under the lean organization, and more when LSS approach is the way production processes are developed (Angelis et al., 2011; Desai et al., 2012; Stone, 2012; Koukoulaki, 2014; Cirjaliu and Draghici, 2016). In those previous researches there have been recognized the negative consequences in the working conditions due to the implementation and development of LSS in the production systems, such as: an increased work pace, workload and work intensification (Nunes et al., 2007; Hasle et al., 2012; Nunes, 2015) which affect the employees' well-being, namely originating fatigue, stress, tension and work-related disorders (Longoni et al., 2010).

Started from these negative effects on the organizations' employees (mainly of the direct productive workers at the operational level) that adopt LSS there have been conclude that a more comprehensive approach is required incorporating a ergonomics oriented approach, since higher productivity is expected with scarce resources, which can compromise the workers well-being and performance.

Practical observations of ours have underlined that LSS is mainly focused on organization's productivity (the system level) but leaves the internal work productivity ignored (the individual and working group level). Managers do not have a clear understanding of the relation between these two types of productivity. Internal work productivity regards the ability of workers to produce more output with no increase in risk of injury or errors, which is a core concern of ergonomics science (Nunes, 2015). As expected, ergonomic interventions can result in positive effects in production performance and this is because of the new created working conditions that support professional well-being of the workers. In addition, for maximizing organizational performance combining the internal working productivity concern in the overall organization's productivity goal is a required condition in the integration process of ergonomics and LSS.

Based on this idea a framework is proposed to help the integration of Ergonomics and LSS based on the DMAIC cycle, which was originated in Six Sigma. In fact, DMAIC is very convenient since it was generalized as an overall framework for process improvement. This generalization can go further; encompassing an integrated approach that incorporates Ergonomic principles, tools and methods. Figure 1 shows the corresponding framework. The proposed framework associates to the LSS procedures used in each phase of the DMAIC cycle an additional ergonomic perspective, as described in Table 1.

Table 1. DMAIC approach with ergonomic interventions

DMAIC cycle	Details on the ergonomic interventions
Define	ergonomic tools (e.g., checklists) and data from existing records (e.g., injuries, accidents) is used to characterize the initial situation of the working conditions and to identify new improvement opportunities
Measure	to complement the establishment of the baseline, ergonomic methodologies are used to evaluate the status of performance metrics in the beginning of the improvement process. These data will be compared to the performance metrics at the end of the process to evaluate the gain resulting from the improvement process
Analyze	ergonomic tools and methodologies are used to pin-point root causes affecting the working conditions. These root causes must be prioritized and selected for elimination on the subsequent step
Improve	the selection and implementation of solutions which eliminate or, at least, mitigate the effect of root causes incorporate ergonomic tools and methodologies which help to identify cost-effective solutions, test such solutions (e.g., using Human CAD modeling), and plan their implementation and deployment
Control	to sustain the gains achieved during the process, a continued monitoring process and training are required, which includes ergonomic tools and methodologies, as well as interventions to raise awareness

The validity of this framework is supported by several successful continuous improvement preliminary studies which were performed including ergonomics and using the DMAIC cycle (Nunes et al., 2007; Nunes, 2015; Cirjaliu and Draghici, 2016). Besides the validation of the framework, it can be concluded that the integration of ergonomics and LSS is possible and beneficial both for the production process and the workers.

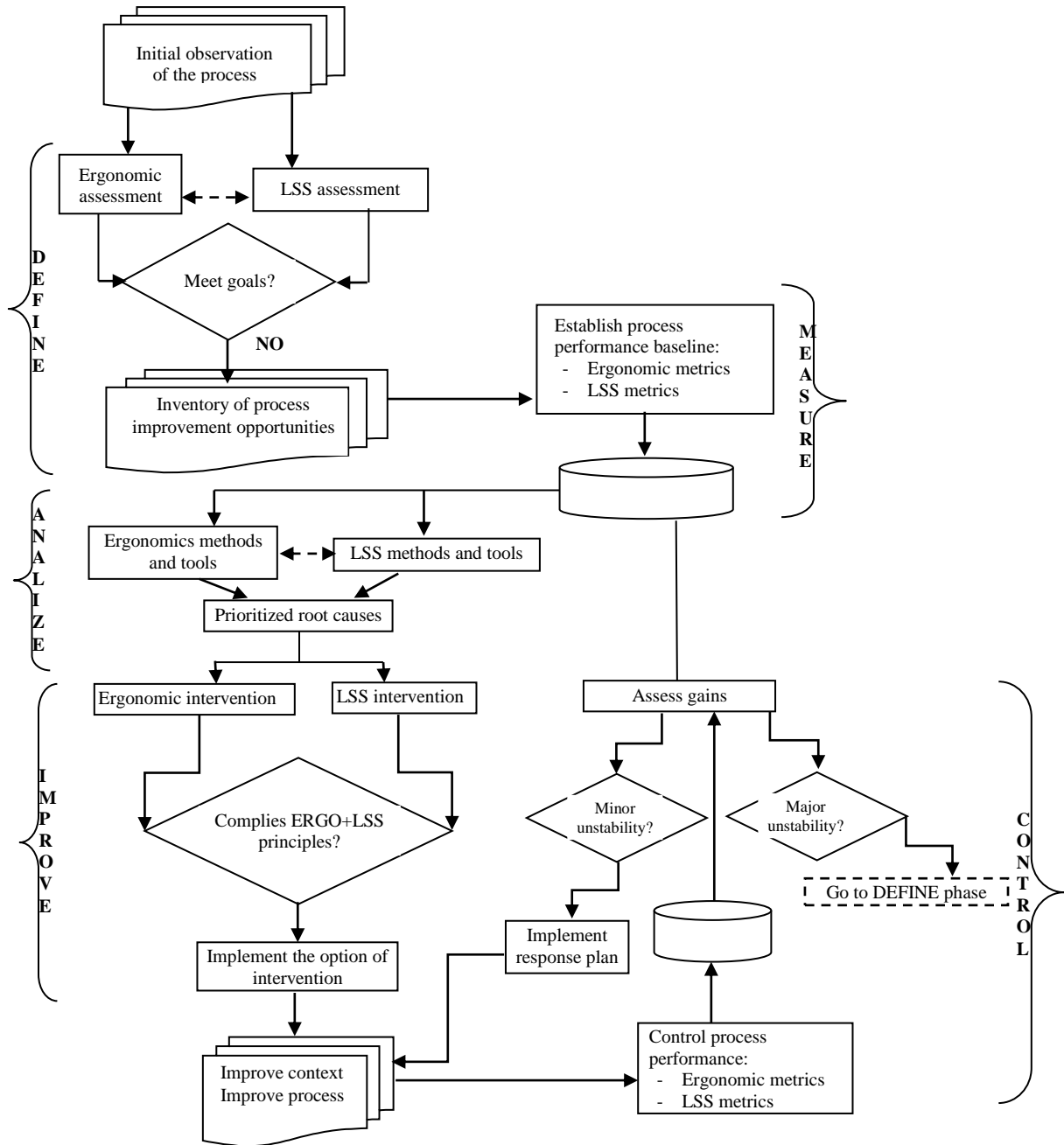


Fig. 1. The proposed approach for the ergonomics and LSS integration

The proposed approach of integrating ergonomics and LSS could be better implemented with a decision support system, as shown in Figure 2. The first knowledge base must be initialized with ergonomic and LSS domain knowledge, developed through a knowledge acquisition process from consultants, experts and from explicit sources of knowledge (e.g., create access to digital libraries). The data, information and knowledge regarding the organizational processes that must be improved have to be gathered and stored in the database, created based on organization evidences, reports, audits etc. The inference process will conduct the execution of the proposed decision support system, interacting with the user (through an adequate interface) providing orientation to the data collection stages, analyzing such data and providing results and advice, or help and guidance regarding the continuous improvement process.

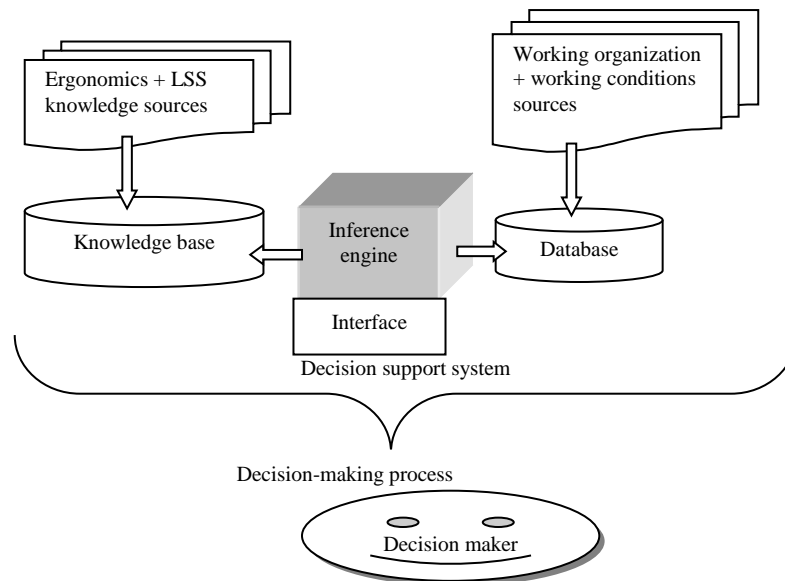


Fig. 2. The architecture of the decision support system based on the ergonomics and LSS integration.

Future researches will develop the reasoning process required for the inference engine as an artificial intelligence approach.

#### 4. Conclusions

In the actual economic context, organizations have implemented continuous improvement approaches to increase competitiveness while facing great market competition, globalization and economic crisis. Managers and researchers have recognized that LSS is a very good approach for continuous improvement.

In the context of our research debate there have been presented (based on the literature review) some negative aspects that can appear when implementing LSS and developing an organization system based on this philosophy. The integration of ergonomics during the LSS implementation has the potential to obtain substantial gains in productivity and to simultaneously improve the working conditions. The proposed approach regarding the integration of ergonomics and LSS based on the DMAIC cycle was presented. The proposed framework associates to the LSS procedures used in each phase of the DMAIC cycle ergonomic tools and methodologies introducing an additional ergonomic perspective.

The proposed approach for the ergonomics and LSS integration (presented in Table 1 and Figure 1) has been developed based on an interdisciplinary research, combining the knowledge from different domains as: ergonomics, quality management, quality control, operation management etc. The proposed approach has demonstrated that ergonomic integration to LSS is possible and could support the continuous improvement processes in a much more proactive manner, by diminishing the work stress and increasing the quality of employees' professional life.

In addition, a decision support system architecture has been proposed to help the decision-making process in the execution of the integrated implementation of ergonomics and LSS continuous improvement processes. This decision support system is useful both for experts in continuous improvement and for managers which may have the awareness but usually lack the means to develop the required steps to implement continuous improvement.

#### References

- Albliwi, S., Antony, J., Implementation of a lean six sigma approach in the manufacturing Sector: a systematic literature review, *Proceedings of the 11th International Conference on Manufacturing Research (ICMR2013)* (2013).
- Angelis, J., Conti, R., Cooper, C., Gill, C., Building a high-commitment lean culture. *Journal of Manufacturing Technology Management*, Vol. 22, No. 5, pp. 569-586, (2011).
- Behrouzi, F., Wong, K. Y., Lean performance evaluation of manufacturing systems: A dynamic and innovative approach, *Procedia Computer Science*, Vol. 3, pp. 388-395, (2011).
- Boatca, M. E., Draghici, A., Carutasu, N., A Knowledge Management Approach for Ergonomics Implementation within Organizations, *Procedia-Social and Behavioral Sciences*, Vol. 238, pp. 199-206, (2018).



- Cherrafi, A., Elfezazi, S., Chiarini, A., Mokhlis, A., Benhida, K., The integration of lean manufacturing, Six Sigma and sustainability: A literature review and future research directions for developing a specific model, *Journal of Cleaner Production*, Vol. 139, pp. 828-846, (2016).
- Cirjaliu, B., Draghici, A., Ergonomic issues in lean manufacturing, *Procedia-Social and Behavioral Sciences*, Vol. 221, pp. 105-110, (2016).
- Desai, D. A., Antony, J., Patel, M. B., An assessment of the critical success factors for Six Sigma implementation in Indian industries, *International Journal of productivity and performance management*, Vol. 61, No. 4, pp. 426-444, (2012).
- Draghici, A., Draghici G., Cross-Disciplinary Approach for the Risk Assessment Ontology Design, *Information Resources Management Journal*, Vol. 26, No. 1, pp. 37-53, (2000).
- Draghici, A., Ivascu, L., Gaureanu, A., Mocan, A., The ergonomics interventions evaluation. A study based on usability. *MATEC Web of Conferences*, Vol. 121, p. 11008, EDP Sciences, (2017).
- Devane, T., Integrating Lean Six Sigma and High-Performance Organizations: Leading the charge toward dramatic, rapid, and sustainable improvement, Vol. 4, John Wiley & Sons, (2004).
- Dul, J., Neumann, W. P., Ergonomics contributions to company strategies, *Applied ergonomics*, Vol. 40, No. 4, pp. 745-752, (2009).
- Dul, J., Bruder, R., Buckle, P., Carayon, P., Falzon, P., Marras, W. S., ... , van der Doelen, B., A strategy for human factors/ergonomics: developing the discipline and profession, *Ergonomics*, Vol. 55, No. 4, pp. 377-395, (2012).
- Fullerton, R. R., Kennedy, F. A., Widener, S. K., Lean manufacturing and firm performance: The incremental contribution of lean management accounting practices, *Journal of Operations Management*, Vol. 32, No. 7-8, pp. 414-428, (2014).
- Hasle, P., Bojesen, A., Langaa Jensen, P., Bramming, P., Lean and the working environment: a review of the literature, *International Journal of Operations & Production Management*, Vol., 32, No. 7, pp. 829-849, (2012).
- IEA, Definition and domains of Ergonomics, International Ergonomics Association, (2018). Retrived from: <https://www.iea.cc/whats/index.html>
- Koukoulaki, T., The impact of lean production on musculoskeletal and psychosocial risks: An examination of sociotechnical trends over 20 years, *Applied Ergonomics*, Vol., 45, No. 2, pp. 198-212, (2014).
- Longoni, A., Pagell, M., Johnston, D., Veltri, A. When does lean hurt?—an exploration of lean practices and worker health and safety outcomes, *International Journal of Production Research*, Vol. 51, No. 11, pp. 3300-3320, (2013).
- Luz Peralta, C. B., Lermen, F. H., Echeveste, M. E. S., de Mello, P. L., Basso, C. R., Lean Manufacturing and ergonomics: a systematic literature review, *Journal of Lean Systems*, Vol. 2, No. 3, pp. 22-36, (2016).
- Melton, T., The Benefits of Lean Manufacturing: What Lean Thinking has to Offer the Process Industries, *Chemical Engineering Research and Design*, Vol. 83, pp. 662-673, (2005).
- Nunes, I.L., Cruz Machado, V., Merging Ergonomic Principles into Lean Manufacturing, in: Bayraksan G et al. (ed), *Proceedings of the 2007 IERC "Industrial Engineering's Critical Role in a Flat World"*, Nashville, Tennessee-EUA, pp. 836-841, (2007).
- Nunes, I. L., Integration of ergonomics and lean six sigma. A model proposal, *Procedia Manufacturing*, Vol. 3, pp. 890-897, (2015).
- Richardson, M., Maspero, M., Golightly, D., Sheffield, D., Staples, V., & Lumber, R., Nature: A new paradigm for well-being and ergonomics, *Ergonomics*, Vol. 60, No. 2, pp. 292-305, (2017).
- Salah, S., Rahim, A., Carretero, J. A., The integration of Six Sigma and lean management. *International Journal of Lean Six Sigma*, Vol. 1, No. 3, pp. 249-274, (2010).
- Stone, K. B., Four decades of lean: a systematic literature review. *International Journal of Lean Six Sigma*, Vol. 3, No. 2, pp. 112-132, (2012).
- Taghizadegan, S., *Essentials of lean six sigma*, Elsevier, (2010).
- Vinodh, S., Gautham, S. G., Ramiya R, A., Implementing lean sigma framework in an Indian automotive valves manufacturing organisation: a case study. *Production Planning & Control*, Vol. 22, No. 7, pp. 708-722, (2011).

## Increasing the quality of occupational safety and health implementations through awareness training for those involved in implementing the Safety Observation Report

Alin Găureanu<sup>a\*</sup>, Anca Draghici<sup>a</sup>, Hugo Weinschrott<sup>a</sup>

<sup>a</sup> Politehnica University of Timisoara, Pta Victoriei 2, 300222 Timisoara, Romania

---

### Abstract

The occupational safety and health (OSH) management field is still a priority for all organizations. Following the observation and implementation of good practices and audits of OSH there have been findings that by questioning employees there could be brought added value to risk identification, sometimes more consistent and more effective than the results of risk assessments carried out by the laborious procedure performed by OSH specialists' domain. The article will present the characteristics and the steps of the Safety Observatory Report (SOR) through the awareness of OSH training. These will contribute to the preparation for the SOR implementation, which leads to the quality and efficiency of the data resulting from the application. Through the training program for the SOR implementation, the qualitative level of the data obtained is increased, is much more real, because they are coming directly from the source and not from the evaluations based on sterile or inappropriate check-lists. The research will underline that SOR could contribute to the increasing of the OSH culture, mainly for the employees, by making them aware that they are part of the system, and do not perceive it as an additional burden.

**Keywords:** Quality, Training, OSH Management, Safety Observatory Report (SOR), sustainability, safety risk assessment

---

### 1. Introduction

Since around 90% of all accidents are caused by unsafe actions, a worker-based safety program must be at the heart of any successful effort to eliminate the adverse effects on employees and sustainable economic development at the organizational level (Krug and Sommers, 2010). In the same time, management concern on OSH culture is a hot subject not only because of the law and regulations in the field, but also, because of the interest on creating work wellbeing and high levels of productivity.

Based on our own observations, in companies located in Timis County (highly industrialized area in the West Region of Romania) the existing programs to improve OSH aspects are mainly concerned with mature, and highly economic potential organizations that are driven by the principles of sustainability. Furthermore, companies cannot have OSH strategies and policies that are assumed and implemented effectively if they are based on sterile, unrealistic, outdated or inappropriate assessments of the organizations' realities that employees face daily. Therefore, they need to be aware of and involved in action to contribute continually to observe and propose measures, considering the human factor of each participant in the OSH system. Thus, employees must be considered the receivers and the primary filter of the observations and proposals related to OSH measures that are implemented in the organization practice.

Such a tool that allows and empowers the active role of employees in the OSH system is the Safety Observation Report (SOR). The purpose of the tool (and associated process) is to engage all employees in the observation of work in progress so that a maximum number of workers, with diverse experiences and perspectives, are involved in the process. This process also provides a method for identifying and documenting safe acts and safe workplace conditions. The main benefits of applying SOR are:

- Identifies and corrects unsafe situations;
- Prevention of injuries and property loss;

---

\* Corresponding author. Tel.: +40-256-403610; fax: +40-256-403610;  
E-mail address: gaureanu.alin@gmail.com

- Raises OSH Awareness and demonstrates leadership's commitment to OSH;
- Evaluates training effectiveness;
- Tests compliance with standards;
- Identifies and corrects weaknesses in OSH;
- Reinforces positive OSH Behavior and improves communication with employees in this field.

An example of SOR content that follow significant instructions is related to the following aspects:

1. Purpose: Performing workplace safety visits to identify and resolve unsafe situations;
2. Process description:
  - Message "I care / We care" - direct discussions with employees in and about their work environment, positive remarks, expressing concern, avoiding sanctions, focusing on effects. SOR is not an audit but an opportunity to interact with workers, providing training and communication perspectives. Questions to learn, not to teach;
  - Involvement on all hierarchical levels;
  - Filtered and centralized proposed actions are discussed monthly and quarterly in special committees;
  - Frequency of SOR from 1 to 4 per month based on assessed, planned or unannounced risks;
  - Visits are short 10-15 min. easy to manage findings;
  - It is done throughout the company's perimeter and in all work exchanges;
  - Examining individual operations and their deployment;
  - Identify safe and insecure practices (which can be instantly intervened);
  - Identify the root causes of unsafe conditions and practices;
  - Appreciate / thank and eventually reward / promote positive OSH behaviors and safe practices;
3. Analyze - Analysis and measurement of collection information:
  - Observation notes during and after the observation visit;
  - Questions and clarifications to get recommendations from operators on improving their OSH at work;
  - Filter and recommend removing / controlling unsafe conditions on a higher hierarchical scale;
4. Corrective actions - Correct prompt of the identified unsafe conditions:
  - Work instructions, use of personal protective equipment, risk assessment may be revised / updated;
  - Information and training of workers for any changes made;
5. Feedback - Offered to employees, direct directors:
  - Formalizing and monitoring corrective actions,
  - Analyzing the effectiveness of SOR after at least 12 months with adjustments to remain relevant.

The occupational safety and health (OSH) management field is still a priority for all organizations. Following the observation and implementation of good practices and audits of OSH there have been findings that by questioning employees there could be brought added value to risk identification, sometimes more consistent and more effective than the results of risk assessments carried out by the laborious procedure performed by OSH specialists' domain. The article will present the characteristics and the steps of the Safety Observatory Report (SOR) through the awareness of OSH training. These will contribute to the preparation for the SOR implementation, which leads to the quality and efficiency of the data resulting from the application. Through the training program for the SOR implementation, the qualitative level of the data obtained is increased, is much more real, because they are coming directly from the source and not from the evaluations based on sterile or inappropriate check-lists. The research will underline that SOR could contribute to the increasing of the OSH culture, mainly for the employees, by making them aware that they are part of the system, and do not perceive it as an additional burden.

## **2. The premise of the research**

In this research there has been considered two premises to outline the improvement of the qualitative aspect regarding the OSH implementation through the SOR tool. The first premise is based on the idea that employees are continually making significant contributions to the discovery and resolution of the hidden risks of injury. The second premise considers that employees can acquire perceptual skills, ready to offer viable solutions to reduce the risk of injury. Both premises have as a common scope: increasing efficiency of OSH activity starting from the bottom to the top of the organizational structure (from employees at the operational level to the top management). Employees and supervisors are actively contributing (on a continuous and realistic basis) to the shaping of OSH strategies, policies and engagements issued by OSH specialists and the organization's top management team. By creating and implementing appropriate and effective OSH procedures, the sterile compliance barrier is removed from existing systems or laws, conformation that inhibits links to the reality and needs of the enterprise, leading to new barriers to perception, misunderstanding, disinterest for prevention, and sustainability at all hierarchical levels. Table 1 presents the information and OSH prevention cycle, seen as a continuous cycle.

Table 1. Cycling OSH prevention by SOR

Top – bottom attributions	Hierarchical levels and OSH responsibilities	Bottom – top (SOR) attributions
Integrated management, responsibility, strategies, OSH policies, considering assessments, good practices (quality systems), legislation	Top and Middle Management	Analyzes integrates and correlates reports for consistency in quality policies integrated with SSH strategies
Internal SSH regulations, strategy takeover, and implementation tracking	OSH Specialist	Filter, quantify, analyze, conclude, report to management and risk assessor
Knowledge, implementation, guidance and supervision of internal policies and regulations	Leaders of workplace	Interviews, involves workers, observes risks and asks for possible measures
Performing and observing procedures with as few risks	Workers / Representatives	Identifies risks and proposes possible measures, actively participates

These convergences and interferences to the contributions to the OSH System Management are found as a guideline within the framework of regulatory acts in the field. These refer to the concept of participatory worker consultation, just as there will be seen that the SOR instrument is used. In Romania, the paragraphs in the OSH Law 319/2006 that consolidate this concept and regulate the workers' advisory aspect, forcing them to participate in OSH decision-making are shown in Table 2 (according to the European Directive 89/391/CEE transpose in the national legislation of OSH Law 319/2006).

Table 2. Legal obligation to use a kind of instrument like SOR

Directive 89/391/CEE, art. 11 – Romanian OHS Law 319/2006, art. 18	Directive 89/391/CEE, art.13 - Romanian OHS Law 319/2006, art. 23
<p>Consultation and participation of workers</p> <p>1. Employers shall consult workers and/ or their representatives and allow them to take part in discussions on all questions relating to safety and health at work.</p> <p>This presupposes:</p> <p>the consultation of workers,</p> <p>the right of workers and/ or their representatives to make proposals,</p> <p>balanced participation in accordance with national laws and/ or practices.</p> <p>...</p> <p>3. Workers' representatives with specific responsibility for the safety and health of workers shall have the right to ask the employer to take appropriate measures and to submit proposals to him to that end to mitigate hazards for workers and/ or to remove sources of danger.</p>	<p>Workers' obligations</p> <p>1. It shall be the responsibility of each worker to take care as far as possible of his own safety and health and that of other persons affected by his acts or omissions at work in accordance with his training and the instructions given by his employer.</p> <p>2. To this end, workers must in particular, in accordance with their training and the instructions given by their employer:</p> <p>...</p> <p>(d) immediately inform the employer and/ or the workers with specific responsibility for the safety and health of workers of any work situation they have reasonable grounds for considering represents a serious and immediate danger to safety and health and of any shortcomings in the protection arrangements;</p> <p>...</p> <p>(f) cooperate, in accordance with national practice, with the employer and/ or workers with specific responsibility for the safety and health of workers, for as long as may be necessary to enable the employer to ensure that the working environment and working conditions are safe and pose no risk to safety and health within their field of activity.</p>

In the practice of various companies, the communication and collaboration on improving OSH activity is often translated into mandatory “hazard” and “near miss” procedural reporting:

- Near miss means that the unplanned event resulting from an error or a malfunction during an activity or related to the disfunction of the working equipment that did not affect the workers, environment, equipment or activity, but through minor changes in circumstances, has the potential to easily produce such consequences in the last minute (circumstance impeded by injury);
- Hazard (dangerous situation) is a concrete, real and actual case, which only lacks the triggering opportunity to produce an accident at any moment.

The difference between the two situations is that if the “near miss” is an already consumed event and fortunately there were no consequences, “the hazard” did not happen, but by its status, it offers the opportunity to occur at any moment an event.

These concepts are a part of goal when using SOR tool, the spearhead of observations and continuous improvement of measures, both being internally solved. SOR tool is not intended to replace the risk assessment, but only to update these assessments by new observations that can be analyzed and considered by the evaluators according to art.15 paragraph 3, letter c) of Romanian OSH Law 319/2006.

### 3. The research approach

#### 3.1. Aspects related to the employee's contribution to OSH

In the first statement, we can argue by presenting the purpose, namely the disclosure of possible accidents that are hidden under one major accident. These should be brought to light by closer observation of the potential risks that can turn the dangers into accidents at work. As have been seen in the example above and summarized in Table 3 it is not constructive to blame and sanction employees for unsafe practices, but it's important to improve the OSH system, according to (Manuele, 2011), who is fighting against Heinrich theories 300-29-1 and the domino (Heinrich, 1959).

Table 3. Approach to system blame - let's improve the system! by (Kleinstaub, 2007)

When Things Go Wrong	
Old approach	New approach
Human error is the cause of accidents:	Human error is a symptom of trouble deeper inside a system.
You are highly trained	You are human
and	and
If you did as trained, you would not make mistakes	Humans make mistakes
so	so
You weren't careful enough	Let's also explore why the system allowed, or failed to accommodate your mistake
so	
You should be PUNISHED	Let's IMPROVE THE SYSTEM!

In order for employees to feel useful and involved in this continuous process of adapting and streamlining OSH measures, they need to acquire skills in this regard by two ways of enhancing the quality of this process:

1. Active involvement as part of the system by increasing confidence in the benefits of its actions. As tools you can use:
  - OSH awareness raising processes at higher levels for a more coherent and uniform application;
  - Influencing workers' perception of their membership of the OSH system;
2. Increase the quality of periodical training through the following tools:
  - Presentation of thematic materials containing images or films;
  - Continuously refine the frames presenting the materials;
  - Appropriate establishment of the frequency of the trainings and the subjects to maintain a balance between the observance of the legal terms and the duration of those trainings, considering the specificities of the workplace and the level of perception of the employees so as not to affect the prevention, not to become disinterested and embarrassed by too dull repeatability or unattractive themes.

The paragraph 2) is part of other future studies. In the context of the research included in this article, we will only address the two instruments under number 1) paragraph.

#### 3.2. SOR awareness training

As an appropriate implementation is specified, it is related to the level of preparedness of those who implement it. Therefore, before creating new tools and procedures that are beneficial for effective SSM management, consideration should be given to preparing participants for these changes. They need to know the SSM concepts, their importance and the role of each in the system. This is only possible through an awareness process involving all hierarchical levels, discussing less well-known aspects, novelties that can attract interest and mobilize explicit and applicative discussions.

Such courses may be provided either by the external partners or by the internal specialists, which may also be included in the provisions of art. 80 letter a) of updated HG 1425/2006, which stipulates that the employer must have appropriate training programs for job managers. Unless these job managers understand their position in the OSH management system, they will be able to convey them to the employees' discussions on the topic, of the understanding and governance of the OSH issue, thus enhancing their leadership status. In the absence of the awareness process before applying the SOR tool, there may be occurred some problems that will alter and hinder the observation process, targeting only a few areas of precarious security (Oswald et al., 2018).

#### 3.3. Influencing the perception of workers

Another tool in raising the quality level of SOR implementation is the applied working method (research method) that refers to the stages of the observation so that the employees do not feel the pressure of regular discussions related to the SOR schema, they do not feel them as an additional task and perceive having an OSH mission in their interest in the organization system (feels attracted, tied and responsible with all participants in that system). "To become a good

observer, he needs to improve his observation skills and have to learn how to observe effectively. The actual observation includes the following key points (Hughes and Ferrett, 2013):

- Be selective;
- You know what to look for;
- Practice;
- Keep an open mind;
- Protect yourself from habit and familiarity;
- Do not be happy with general impressions;
- Record systematic observations.”

The need for processes of awareness and influence of perception will be distinguished from the conceptualization of SOR and the steps to be taken to achieve it.

#### **4. The quality of SOR through conceptual similarities already demonstrated as effective**

We can associate SOR as a collection tool for Root Cause Analysis (RCA)(Zhou et al., 2013; Ferjencik, 2010; Ferjencik, 2014). This analysis can be performed using the 5W Method (5 Way - Why?) which is derived from the Six Sigma methodology (following the Define – Measure – Analysis – Improve – Control cycle, DMAIC) (Tarvin and Tarvin, 2016). In this regard, we can recall a possible similarity in the Key Performance Indicators (KPI) approach, which has a top-down and bottom-up approach, as we can see from the SOR approach (Gerbec and Kontić, 2017).

Practically, SOR tool comes to complete the work of (Hughes and Ferrett, 2013; p. 91 – Supervisors, point 4) and to argue with the multiple methods of continuous risk identification, leaving the analysis aimed at extracting information directly from the employees, and the reporting, analysis, evaluation, and resolution of these issues by the OSH specialists, assessors and managers through the methods already listed.

This SOR procedure is not the only way of working, but it is also seen as a Safety Observation Tour (SOT) or Safety Observation System (SOS) or even Near Miss Reporting. All of them have the same purpose to involved employees into the OSH practice, to assume responsibilities for themselves and those around them, and to encourage employees at all levels to act and create a positive change (Krugh and Sommers, 2010). This expected behavior is expecting to have a positive impact on the OSH culture.

In support of the concept of increasing the quality of SOR tool implementation, the Safety Trail Observation Plan (STOP) (STOP ® Safety Training Observation Program Overview, 2016) has to be mention. Furthermore, under the same auspices of safety observation, even tools for the continuous improvement of operational safety in the nuclear energy industry (Cournoyer et al., 2011) have been developed with the help of the behavior-based safety observation program (ATOMICS-Allowing Timely Observations Measures Increased Commitment to Safety) within the Glovebox Safety Program (GSP).

By the employees’ assessment process and making them aware that they are part of the safety system, it is basically transferring responsibilities to them and others as they obtain a distributed security according to the Gaining Distributed Safety (GDS) / Distributed Safety Management (DSM) method as an observation Behavior-Based Safety Culture Assessment. This is based on an AsSeVi Survey Tool questionnaire developed in 2013 that aims to integrate coherently, responsibly, participation, commitment, compliance (Sheffick and Grillo, 2011; Amaya, et. al, 2018).

Prior to implementation and during the implementation of SOR procedure, there must be continuously analyze the cost balance needed to develop such programs for company profitability. “Customization is expected to require more resources; hence its realization depends on the capability, objectives and vision of each organization” (Karanikas et al., 2017). “Instead of providing robust safety knowledge, the SOR system was instead a tool that could be used to challenge their own performance” (Oswald et al., 2018).

Resource, staff and time investments to carry out these activities must not exceed the limits of the ALARP (As Low As Reasonably Practicable) management rules. The cost involved in reducing the risk further would be grossly disproportionate to the benefit gained (Jones-Lee and Aven, 2011; Ale et al., 2015; Nw Zealand Government, 2017). ALARP principles are also found in the motivation of elaboration of EEC Directive 89/391 “in accordance with Article 118a of the European Union Treaty, these directives must avoid imposing administrative, financial and legal constraints which would hinder the creation and development of small and medium-sized enterprises”.

#### **5. Conclusions**

SOR tool demonstrates that for a qualitative improvement in the application of OSH prevention principles, there must be a broader vision in an already established scientific spectrum. It is not an unpredictable invention, but it is an adequate application of prevention obligations under OSH legislation. To preserve the proven quality of the application, this must be accompanied by quality implementation through awareness-raising, continuous training through direct contact with every job, analysis, feedback and ongoing adjustments.

Some qualitative aspects of continuous training and improvement of participants in the SOR process, implicit in the OSH system in which everyone should feel involved, will be the subject of other papers. The objective of the future researches is aligned with the logo of (Kleinstüber, 2007): “If we can predict it: we can prevent it!”

## References

- Ale, B. J. M., Hartford, D. N. D., Slater, D., ALARP and CBA all in the same game, *Safety Science*, Vol. 76, pp. 90–100, (2015).
- Amaya, N., Rovira, M. D., del Cerro, S., Grillo, M., Nomen, R., Sempere, J., Distributed Safety Management as a tool for creating a safety culture in university students and future professionals, *Journal of Loss Prevention in the Process Industries*, (2018).
- Cournoyer, M. E., Kleinstaub, J. F., Garcia, V. E., Wilburn, D. W., George, G. L., Blask, C. L., Safety observation contributions to a glovebox safety program, *Journal of Chemical Health and Safety*, Vol. 18, No. 5, pp. 43–55, (2011).
- Ferjencik, M., Root cause analysis of an old accident in an explosives production plant, *Safety Science*, Vol. 48, No. 10, pp. 55–68, (2010).
- Ferjencik, M., IPICA\_Lite-Improvements to root cause analysis, *Reliability Engineering and System Safety*, Vol. 131, pp. 1–13, (2014).
- Gerbac, M., Kontić, B. K., Safety related key performance indicators for securing long-term business development - A case study, *Safety science*, Vol. 98, pp. 77–88, (2017).
- Heinrich, H. W., *Industrial accident prevention: a scientific approach*. New York: McGraw-Hill, (1959).
- Hughes, P., Ferrett, E., *Health & Safety*, Butterworth-Heinemann, 5th ed., Vol. 2013, Elsevier Ltd., (2013).
- Jones-Lee, M., Aven, T., ALARP—What does it really mean? *Reliability Engineering & System Safety*, Vol. 98, No. 8, pp. 877–882, (2011).
- Karanikas, N., Melis, D. J., Kourousis, K. I., The Balance Between Safety and Productivity and its Relationship with Human Factors and Safety Awareness and Communication in Aircraft Manufacturing, *Safety and Health at Work*, (2017).
- Kleinstaub, J., *Safety Observations*, Los Alamos (ATOMICS program), (2007).
- Krugh, K. A., Sommers, J. R., Safety observation system and near miss reporting programs: Methods to maintain employee engagement in behavioral based safety practices, *IEEE Cement Industry Technical Conference (Paper)*, (2010).
- Manuele, F. A., Heinrich Dislodging Two Myths From the Practice of Safety, *Professional Safety*, pp. 52–61, (2011).
- New Zealand Government. Reasonably Practicable, (2017). Retrieved from: [www.worksafe.govt.nz](http://www.worksafe.govt.nz)
- Oswald, D., Sherratt, F., Smith, S., Problems with safety observation reporting: A construction industry case study, *Safety Science*, Vol. 107 (November 2016), pp. 35–45, (2018).
- Sheffick, R., Grillo, M., Exploring the Emerging Trends and Practices for Process Safety, AICHE Academy, 2011 AICHE Spring Meeting and Global Congress on Process Safety, (2011). Retrieved from <https://www.aiche.org/conferences/aiche-spring-meeting-and-global-congress-on-process-safety/2011/proceeding/paper/58c-exploring-emerging-trends-and-practices-process-safety-0>
- STOP ® Safety Training Observation Program Overview, (2016). Retrieved from [www.training.dupont.com](http://www.training.dupont.com).
- Tarvin, P., Tarvin, P., Six Sigma, *Leadership and Management of Machining*, pp. 97–103, (2016).
- Zhou, S., Sun, J., Li, K.-P., Yang, X., Development of a Root Cause Degree Procedure for measuring intersection safety factors, *Safety Science*, Vol. 51, pp. 257–266, (2013).

## Reducing the risk of slipping on ice by selecting appropriate protective footwear

Nicoleta Crăciun\*, Alina Trifu

*I.N.C.D.P.M. „Alexandru Darabont” 35 A, Ghencea Bld, Bucharest*

---

### Abstract

The existence of numerous jobs in construction, maintenance, interventions, etc., where workers have to operate in very cold environments, often results in the occurrence of various accidents due to slipping on frozen surfaces. Considering the risks to which workers are exposed, the article presents the results of studies on determination the slip resistance on ice for different types of soles, while stressing the importance of properly selecting the footwear to prevent the risk of injury and occupational disease.

*Keywords:* coefficient of friction, ice, accident prevention, protective footwear

---

### 1. Introduction

One of the most frequent causes of injury and occupational diseases in many economic sectors is exposure of workers to very low temperatures. At national and international level, there are many jobs such as in construction, agriculture, commercial fishing, forestry, mining, energy, food, etc. where workers have to work a few hours a day in environments with low-temperature ( $t \leq 10\text{ }^{\circ}\text{C}$ ) or very low temperature ( $t \leq -20\text{ }^{\circ}\text{C}$ ).

Thus, in addition to the specific hazards of the work they perform, workers are exposed to the risks arising from exposure to cold.

The main risks that affect health by exposure to low and very low temperatures are: hypothermia, frostbite and accidents due to slipping. If some dangers encountered in such jobs may be avoided (e.g. by wearing clothing articles with thermal properties), others, such as slipping on frozen surfaces are more difficult to avoid and often cause particularly serious accidents. In relation to hand injuries, for example, when the same degree of injury will permit the worker to resume work, in case of injuries to the legs, it is necessary to interrupt the work over a much longer period of time due to the difficulty and even the impossibility of putting up one's footwear. If the accidents occurring on the toes are not always considered the worst, the accidents occurring on the paw of the foot at ankle level should be considered among the most serious.

Due to this fact, it is considered imperative to reduce work accidents caused by falling on frozen surfaces by developing criteria for the selection of the protective footwear. This necessity is imposed not only by the fact that the modes of manifestation of slip risks are very diverse, and inadequate protection against cold (such as the provision of inappropriate protective equipment) could introduce new risk factors that would change the worker's normal behaviour, rendering him more prone to errors and accidents, but also the lack of specific testing methods leading to the establishment of criteria for the selection of the footwear.

### 2. Identification of the risk factors specific to the movement on frozen surfaces

If for activities carried out in normal environments a number of problems have been resolved by the appearance of method standards and the setting of threshold values that allow the evaluation and determination of the protective features of the PPE used, the same cannot be said about the activities carried out in environments with low temperatures where the multitude of risk factors and their possible cumulative effects appear to further complicate measures to prevent accidents and occupational diseases.

---

\* Corresponding author. Tel.: +40 0729909558.  
E-mail address: nicoleta2k3@yahoo.com.

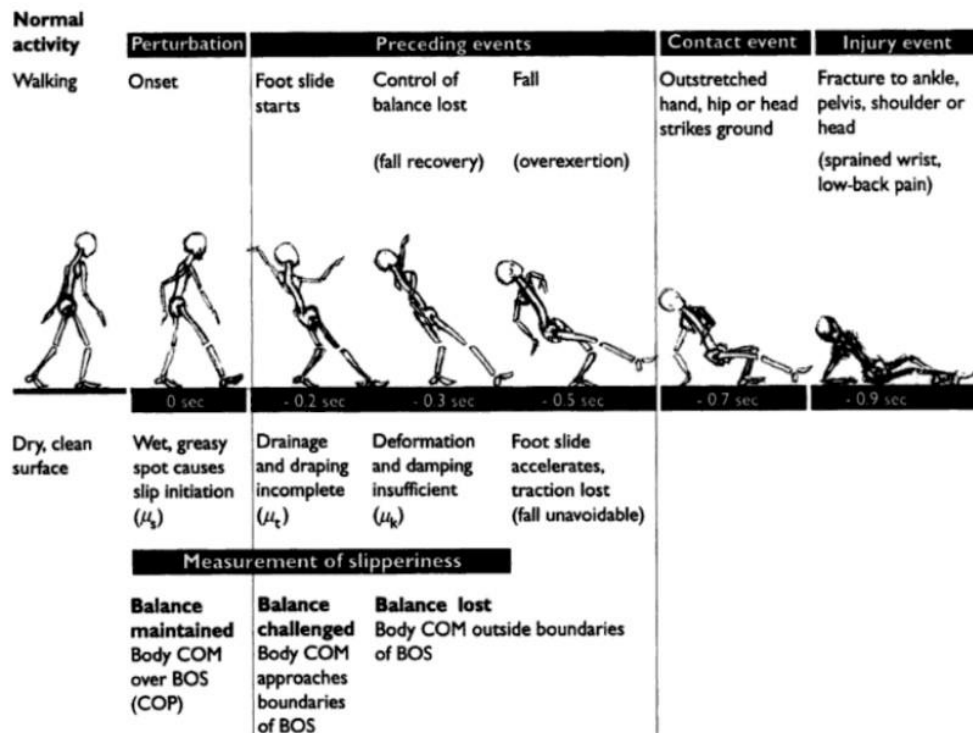


Research in the field has demonstrated that accidents due to slipping are not purely random but rather predictable events with known risk factors that may be extrinsic (environmental factors), intrinsic factors (human factors) or mixtures (system factors).

If human factors include parameters such as walking behaviour, walking speed, weight, physical fitness and observation state (the ease with which slippery floors can be recognized as such), environmental factors include the characteristics of the surface on which the movement takes place, footwear types, contaminants, altitudes, lighting, etc.

In order to identify the main causes of the accident due to slipping, researchers from Finland and Germany followed both the phenomena of static friction (considered to be important to prevent slippage and dynamic friction) avoiding the fall of a subject due to intense movements of the body to regain balance) on different surfaces and lubricants.

Starting from the concept that the main risk factor for slippage is the sudden loss of foot and surface adherence, scientists in Finland and Germany have developed a conceptual scenario of the events that take place during the journey, from the contact of the heel with the soil, until the fall, is shown in fig. 1.



([https://books.google.ro/books?hl=en&lr=&id=TV3U-AHbFScC&oi=fnd&pg=PR6&dq=related:Oc-qLdFko84J:scholar.google.com/&ots=\\_FFqcXfrZI&sig=rr3ZZ4c\\_JgbTd-3lPwDujq7CETk&redir\\_esc=y#v=onepage&q&f=true](https://books.google.ro/books?hl=en&lr=&id=TV3U-AHbFScC&oi=fnd&pg=PR6&dq=related:Oc-qLdFko84J:scholar.google.com/&ots=_FFqcXfrZI&sig=rr3ZZ4c_JgbTd-3lPwDujq7CETk&redir_esc=y#v=onepage&q&f=true))

Fig. 1. Conceptual scenario of events occurring during walking

At European level, the results of research on surfaces similar to those encountered in most occupational accidents have been materialized through both the appearance of method standards (such as EN 13287) and by the establishment of coefficients of friction on different surfaces (ceramic and steel) and contaminants (detergent and glycerine) below which slipping occurs.

Studies conducted at international level have highlighted the following factors specific to the footwear and general environmental conditions that affect slip resistance:

- ice surface characteristics, the ice slip risk is the property of this type of surface and can be amplified by the presence or absence of moisture - the water layer, which occurs mainly at relatively high temperatures, associated with the cold environment rather than what which PPE standards call "cold".
- the material from which the sole is made of;
- non-slip surface;
- the shape and height of the crampons;

In conclusion, identifying the characteristics that shoes should have in order to provide adequate protection for the movement on frozen surfaces is a challenge, both nationally and internationally.

### 3. Identifying the characteristics of the footwear to reduce the risk of slipping

In order to identify the protective footwear elements that could reduce the risk of slipping on frozen surfaces, researchers from the INCDPM developed a specific test method in which testing was based mainly on the setting of test conditions and selecting the protective footwear.

When determining the test conditions, the following was taken into account:

- potential temperature at place in which work was performed in:
  - **outdoor during winter in Romania** - Romania has a temperate continental climate with cold winters in which the cold air from the East brings temperatures up to  $-20^{\circ}\text{C}$  or even below (the record is  $-38.5^{\circ}\text{C}$  degrees at Bod, near Brasov, registered on January 25, 1942). The snow is not abundant compared to other European countries, due to the lack of rainfall and frequent temperature increases.
  - **enclosed spaces**, where workers, due to the specificity of the activity (food industry), are exposed to low temperatures between  $0^{\circ}\text{C}$  and  $+10^{\circ}\text{C}$  (in the case of fresh products) and temperatures below  $-20^{\circ}\text{C}$  (in the case of frozen products).
- the test conditions for the soles and the heel to be placed on the test surface according to EN 13287 (Personal Protective Equipment - Footwear - Testing Method for Slip Resistance).


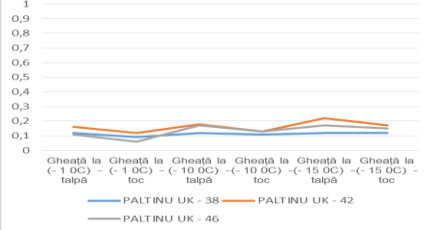

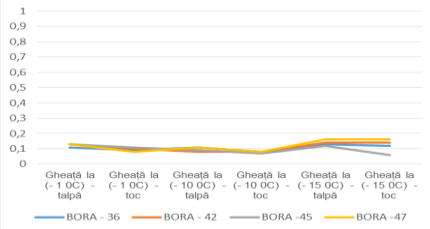

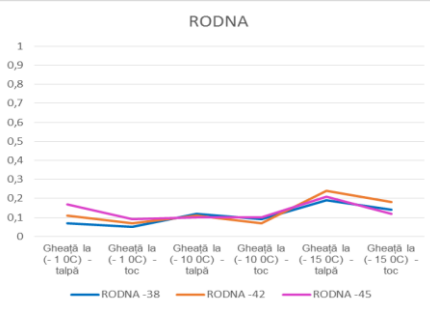

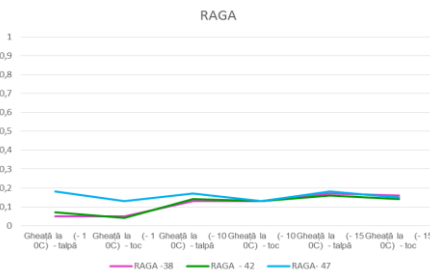
In order to identify the optimal protection features that should be provided by the sole to provide protection against slipping on ice, the shoe selection was made on the basis of the following criteria:

- to be made of different material;
- the sole has different profiles and sizes.

### Results of the test series

Taking into account the criteria set above, 18 shoe models of different sizes with sole made of different materials were subjected to the sliding test on frozen surfaces (at  $-1^{\circ}\text{C}$ ,  $-10^{\circ}\text{C}$ ,  $-15^{\circ}\text{C}$ ). In table 1 are presented the results of the test series made on soles made of the same material but with different profiles.

Table 1. Results of slip resistance of dual-density polyurethane rubber soles

Sole profile	Characteristics	Obtained results
	<ul style="list-style-type: none"> <li>- Double density polyurethane rubber</li> <li>- Hardness <math>62^{\circ}\text{Sh}</math>;</li> <li>- Surface with cleats:</li> <li>- Previous: <math>\geq 0,50 \times \text{L}</math></li> <li>- Posterior: <math>\geq 0,32 \times \text{L}</math></li> <li>- Cleats height: <math>(4,85 \div 6,1) \text{ mm}</math></li> </ul>	<p><b>PALTINU UK</b></p> 
	<ul style="list-style-type: none"> <li>- Double density polyurethane rubber</li> <li>- Hardness <math>56^{\circ}\text{Sh}</math>;</li> <li>- Surface with cleats:</li> <li>- Previous: <math>\geq 0,49 \times \text{L}</math></li> <li>- Posterior: <math>\geq 0,30 \times \text{L}</math></li> <li>- Cleats height: <math>(3,4 \div 5,3) \text{ mm}</math></li> </ul>	<p><b>BORA</b></p> 
	<ul style="list-style-type: none"> <li>- Double density polyurethane rubber</li> <li>- Hardness <math>66^{\circ}\text{Sh}</math>;</li> <li>- Surface with cleats:</li> <li>- Previous: <math>\geq 0,55 \times \text{L}</math></li> <li>- Posterior: <math>\geq 0,33 \times \text{L}</math></li> <li>- Cleats height: <math>(3,4 \div 3,8) \text{ mm}</math></li> </ul>	<p><b>RODNA</b></p> 
	<ul style="list-style-type: none"> <li>- Double density polyurethane rubber</li> <li>- Hardness <math>66^{\circ}\text{Sh}</math>;</li> <li>- Surface with cleats:</li> <li>- Previous: <math>\geq 0,47 \times \text{L}</math></li> <li>- Posterior: <math>\geq 0,34 \times \text{L}</math></li> <li>- Cleats height: <math>(3,5 \div 4,0) \text{ mm}</math></li> </ul>	<p><b>RAGA</b></p> 





By analyzing the friction coefficient values obtained on ice slipping for the four models whose sole is made of double density polyurethane rubber, the following conclusions can be drawn:

- the coefficient of friction is influenced by the arrangement of the cleats;
- the coefficient of friction is influenced by the nature of the material, since it has been observed that at ice surface temperatures of  $-15^{\circ}\text{C}$ , the value of the friction coefficient is higher in the case of soles made of double density polyurethane rubber with higher hardness;
- the height of the cleats does not influence the value of the friction coefficient;

In order to obtain objective conclusions regarding the identification of the soles' characteristics that may influence the value of the friction coefficient on ice slip, all the values obtained on the sole size 42 were compared (see table 2).

Table 2. Results of slip resistance obtained on the sole size 42

Sole profile	Sole characteristics	Ice to $-1^{\circ}\text{C}/\text{sole}$	Ice to $-1^{\circ}\text{C}/\text{heel}$	Ice to $-10^{\circ}\text{C}/\text{sole}$	Ice to $-10^{\circ}\text{C}/\text{heel}$	Ice to $-15^{\circ}\text{C}/\text{sole}$	Ice to $-15^{\circ}\text{C}/\text{heel}$
	- Double density polyurethane rubber - Hardness 62 $^{\circ}\text{Sh}$ ; - Cleats height: $(4,85 \div 6,1)$ mm	0,16	0,12	0,18	0,13	0,22	0,17
	- Double density polyurethane rubber - Hardness 56 $^{\circ}\text{Sh}$ ; - Cleats height: $(3,4 \div 5,3)$ mm	0,13	0,1	0,08	0,08	0,14	0,14
	- Double density polyurethane rubber - Hardness 66 $^{\circ}\text{Sh}$ ; - Cleats height: $(3,4 \div 3,8)$ mm	0,11	0,07	0,11	0,07	0,24	0,18
	- Double density polyurethane rubber - Hardness 66 $^{\circ}\text{Sh}$ ; - Cleats height: $(3,5 \div 4,0)$ mm	0,07	0,04	0,14	0,13	0,16	0,14
	- cauciuc vulcanizat monodensitate - Hardness 67 $^{\circ}\text{Sh}$ ; - Cleats height: $(6,5 \div 6,8)$ mm	0,09	0,04	0,11	0,08	0,09	0,07
	- Monodensity vulcanized rubber - Hardness 67 $^{\circ}\text{Sh}$ ; - Cleats height: $(6,5 \div 6,8)$ mm	0,12	0,06	0,15	0,11	0,19	0,08
	- Monodensity vulcanized rubber - Hardness 64 $^{\circ}\text{Sh}$ ; - Cleats height: $(6,5 \div 6,8)$ mm	0,06	0,06	0,16	0,13	0,23	0,23
	- Double density polyurethane rubber - Hardness 62 $^{\circ}\text{Sh}$ ; - Cleats height: 5,2 mm	0,14	0,1	0,23	0,19	0,22	0,2
	- double density polyurethane - Hardness 60 $^{\circ}\text{Sh}$ ; - Cleats height: $(5,0 \div 6,0)$ mm	0,14	0,10	0,23	0,19	0,22	0,20
	- styrene-butadiene rubber - Hardness 66 $^{\circ}\text{Sh}$ ; - Cleats height: $(7,2 \div 7,7)$ mm	0,06	0,05	0,17	0,10	0,20	0,15
	- styrene-butadiene rubber - Hardness 63 $^{\circ}\text{Sh}$ ; - Cleats height: $(5,0 \div 6,2)$ mm	0,12	0,03	0,14	0,11	0,18	0,13

Sole profile	Sole characteristics	Ice to -1 °C/sole	Ice to -1 °C/ heel	Ice to -10 °C/sole	Ice to -10 °C/heel	Ice to -15 °C/sole	Ice to -15 °C/heel
	- styrene-butadiene rubber - Hardness 63 °Sh; - Cleats height: (4,7 ÷ 5,3) mm	0,16	0,08	0,18	0,17	0,23	0,19
	- styrene-butadiene rubber - Hardness 61 °Sh; - Cleats height: (3,5 ÷ 4,7) mm	0,1	0,07	0,18	0,12	0,18	0,16
	- polyolefin thermoplastic polymers / polymers; - Hardness 59 °Sh; - Cleats height: (6,5 ÷ 6,8) mm	0,13	0,13	0,26	0,16	0,36	0,12
	- Polymer blend sole (vinyl polychloride and antistatic nitrile rubber); - Hardness 69 °Sh; - Cleats height: (6,0 ÷ 6,5) mm	0,09	0,05	0,12	0,09	0,14	0,15

Analyzing the values obtained after the test series, it can be said that the coefficient of friction value:

- is influenced by the nature of the material from which the sole is made - the soles made of " styrene-butadiene rubber" and "polyolefin thermoplastic polymers / polymers" have a higher slip resistance than those made from monodensity vulcanized; double density polyurethane rubber or blends of polymers;
- is influenced by how the cleats are positioned on the sole surface;
- it is not influenced by the height of the cleats;
- it is influenced by the condition of the walking surface; it has been found that regardless of the nature of the material from which the sole is made, the less frozen items (e.g., -1 °C) obtain the lowest friction coefficients, which implies a high risk of slipping

#### 4. Criteria for selecting the protective footwear to reduce the risk of slipping

Since there may be a multitude of footwear models on the market, the selection of appropriate footwear to ensure a high level of protection against the risks at the workstation is only made after an appropriate assessment, taking into account:

- analyzing and assessing risks that cannot be avoided by other means;
- defining the characteristics that the personal protective equipment must possess in order to be effective against the risks against which it assures protection, taking into account any risks that the equipment itself may create;
- comparing the characteristics of the individual protective equipment available on the market with those identified in point b);
- the presence of the "EU" conformity marking accompanied by the number of the standard / standards whose requirements it meets.

Taking into account the above and the fact that the frozen surfaces are influenced by the working environment temperature, in the case of cool and cold environments, a shoe which will provide protection against cold, the marking of which must contain:

- size;
- manufacturer's identification mark,
- manufacturer's type designation;
- year of manufacture and at least quarter,
- the "EU" conformity marking - the presence of the conformity marking certifies that the footwear has been the subject of a certification procedure at a notified body and complies with the requirements of Regulation (EU) 2016/425 of the European Parliament and of the Council of 9 March 2016 on machinery individual protection and repealing Council Directive 89/686 / EEC
- the number and year of the standard that it complies with their requirements (eg EN ISO 20346:2014 - for protective footwear, EN ISO 20347: 2012 - for occupational footwear, EN ISO 20345:2011 - for safety footwear, etc.) as well as other symbols corresponding to the protection provided, such as:
  - the symbol "CI" - the specific marking corresponding to the insulation of the lower assembly against the cold;
  - one of the symbols:
    - "SRA" - which certifies that the shoes provide protection against sliding when moving on ceramic flooring covered with detergent solution;
    - "SRB" - which certifies that the shoe provides protection against slipping on steel (metallic) coatings covered with glycerine (viscous substances);

- "SRC" - which certifies that the shoes provide protection against slippage on both ceramic flooring covered with detergent solution and on steel (metallic) flooring covered with glycerine (viscous substances);

With regard to ice-slip protection, there are not enough studies at international level to substantiate a technical document (guideline, international or national standard, etc.) containing specifications, including labelling encodings. Therefore, in addition to the above-mentioned recommendations on shoe selection criteria, users may refer to the conclusions set out in Chapter 3, namely, to purchase footwear with "rubber" sole or "polymer compounds-thermoplastic polyolefin elastomers" sole.

#### **4. Conclusions**

Since at international level there are not enough studies to substantiate a technical document (guideline, international or national standard, etc.) containing specifications, including ice marking resistance coding, the article presents both the structural features of the sole footwear to provide protection against slipping on the ice as well as selection criteria for it.

#### **References**

- Mäkinen, T. M., Hassi J., *Health Problems in Cold Work*, Industrial Health, No. 47, pp 207–220 (2009).
- Grönqvist R. et al., *Human-centred approaches in slipperiness measurement*, Ergonomics, No 44(13), pp 1167–1199 (2001).
- Grönqvist R. et al., *Measurement of slipperiness*, (2003).
- HOTĂRÂRE Nr. 1048 din 9 august 2006 privind cerințele minime de securitate și sănătate pentru utilizarea de către lucrători a echipamentelor individuale de protecție la locul de muncă
- EN ISO 20347:2012, *Personal protective equipment — Occupational footwear (ISO 20347:2012)*

## Managing the activities of authorization to practice trades and professions in terms of safety and health at work

Băbuț Gabriel Bujor<sup>a,\*</sup>, Moraru Roland Iosif<sup>a</sup>

<sup>a</sup>University of Petroșani, University Street, no. 20, 332006-Petroșani, Romania

---

### Abstract

The fulfillment by the employer of the legal obligation to authorize in terms of safety and health at work the practice of trades and professions under specific legislation is currently encumbered by the lack of clear and coherent legal regulations setting the occupational categories to be approved, the authorization methodology and the competent regulatory authorities. This lack of regulation or even "legal vacuum" generated a lot of confusion in practice and led to conflicts between various stakeholders, with harmful effects in terms of ensuring safe and healthy workplaces. As a result, there is an urgent need to undertake a study establishing the constituent elements of the legislative and methodological framework to be adopted and implemented in Romania in order to achieve a modern and adequate management of the activities to authorize the practice of trades and professions in terms of safety and health at work. From this perspective, this paper analyzes the evolution of national law in the field of authorization of trades and professions in terms of safety and health at work, are identified the professional categories whose authorization is governed by specific legislation and is presented for each personnel category the authorization methodology applied by the appropriate regulatory authority. Studies and research have enabled the identification of other professional categories engaged in hazardous activities with high risk of injury and occupational disease, for which the opportunity of an internal or external authorization is required to be analyzed.

*Keywords:* management; authorization; trade; profession; safety and health at work;

---

### 1. Introduction

Authorizing to practice trades and professions in terms of safety and health at work is an activity of primary importance in ensuring safe and healthy working conditions especially for workers engaged in hazardous activities with high risk of injury and occupational disease (Băbuț and Moraru, 2018).

Authorization is always preceded and conditioned by the acquisition, development or completion of a set of knowledge, skills and competencies through qualification, training or specialization programs. While vocational training to pursue specific professions in the field of health and safety at work was the subject of normative acts and studies, both on national level (Băbuț et al., 2010; Moraru et al., 2014) and worldwide (Ricci et al., 2016; Tappura et al., 2019), the training required to authorize the occupations and professions from the point of view of safety and health at work did not benefit either from a clear and coherent legislative framework or from dedicated studies.

The analysis of the current state of knowledge in the field of authorization of trades and professions from the point of view of safety and health at work revealed that to this issue were devoted very few specialty studies, studies which generally concerned only a particular sector of activity (Fuentes, 2009; Furusten, 2013; Pupăzan et al., 2015).

As a logical consequence of the aforementioned aspects, there was a pressing need to carry out a study that, starting from the critical analysis of the current legislative framework and the current realities and trends in the labor market, to allow the achievement of a modern management of the activities to authorize the practice of trades and professions in terms of safety and health at work.

---

\* Corresponding author. Tel.: +40 732 971 484; fax: +40 254 543 491.  
E-mail address: gabriel\_babut@yahoo.com.

## 2. Legal requirements

The regulation of the activities of authorizing the trades and professions from the point of view of safety and health at work has been a constant concern of the national authorities with attributions in the field, the evolution of the legislative framework being influenced in particular by the scientific and technical progress.

The obligation of the management of the legal entity as well as of the individual legal person to take „*measures for the authorization of the exercise of the trades and professions stipulated in the norms of labor protection*” was introduced in the national legislation by the provisions of article 18, paragraph 1 (j) of the Law no. 90/1996 on Labor Protection - with the subsequent amendments and completions. This obligation was detailed by the provisions of Annex 1 of Order no. 578/DB 5840/1996 of M.M.P.S. and M.S. for the approval of the General Labor Protection Norms, which established the professional categories of personnel to be authorized and the regulatory normative acts (Table 1).

Table 1. Professional categories of personnel to be authorized according to the provisions of Annex 1 of Order no. 578/DB 5840/1996 of M.M.P.S. and M.S.

No.	Profession	Sector of activity
1.	Electrician	Production and distribution of electricity
		Mining industry
		Other sectors of activity
2.	Underground welding vulcanization, soldering, insulating table casting	Mining industry
3.	Energy staff for mining blasting gear	Mining industry
4.	AGR expert	Mining industry
		All sectors of activity with explosive environments
5.	Mechanics of extraction machinery	Mining and hydrotechnics
6.	Signal givers	Mining and hydrotechnics
7.	Mine igniter	Mining industry and other sectors of activity
8.	Technical leaders and managers of occupational safety compartments	Mining industry
9.	Mine rescuer	Mining industry and offshore activities
10.	Welders for mechanical pressure and lift installations	All sectors of activity
11.	Crane operators	All sectors of activity
12.	Translating mechanics	All sectors of activity
13.	Loaders	All sectors of activity
14.	Fireman	All sectors of activity
15.	Lifters	All sectors of activity
16.	Trolley mechanics	All sectors of activity
17.	Operator at laboratory in thermal power plants	Production and distribution of thermal energy
18.	Abrasive body mounting operator	All sectors of activity
19.	Manipulating trolley operators(motor, electric forklift) and electric car driver	All sectors of activity
20.	Authorized plumber (degree I, II, III) for design and use works execution of gas distribution	All sectors of activity
21.	Technicians and workers performing pre-stressing reinforcement work on concrete prefabricated elements	Construction materials industry
22.	Refrigerationist, refrigerationist master; intervention mechanics and electricians for refrigeration plants	Food industry and other sectors of activity
23.	Worker with radioactive source	All sectors of activity

The transposition into the national legislation of the *acquis communautaire* in the field of safety and health at work led to the repeal of Law no. 90/1996 and subsequent normative acts, including Order no. 578/DB 5840/1996 of M.M.P.S. and M.S. As a result, there is no longer a list of trades and occupations to be authorized from the point of view of safety and health at work, the list in Annex 1 of Order no. 578/DB 5840/1996 of M.M.P.S. and M.S. not being included, possibly in an updated form adapted to the new labor market realities, in a normative act in force.

At present, the authorization to practice trades and professions from the point of view of safety and health at work is regulated through the provisions of:

- article 13, letter I, of the Law no. 319/2006 on Safety and Health at Work - with the subsequent amendments and completions: „*in order to ensure safety and health at work and to prevent accidents at work and occupational diseases, employers have the following obligations: ... i) to take measures to authorize the exercise of trades and professions under the specific legislation*”;



- article 15, paragraph 1 (12), of the Government Decision no. 1425/2006 approving the Methodological Norms for the application of the provisions of the Law on Safety and Health at Work no. 319/2006 - with the subsequent amendments and completions: „the prevention and protection activities carried out within the enterprise and/or the unit are the following: ... 12. the records of the trades and professions stipulated by the specific legislation, for which it is necessary to authorize their practice”.

Failure to comply to the employer's legal obligation to take measures to authorize the exercise of trades and professions provided for by the specific legislation constitutes a contravention and shall be sanctioned by a fine from 4,000 to 8,000 lei, according to article 39, paragraph 4 of Law no. 319/2006. Also, the failure to observe the employer's statutory obligation to take into account the worker's occupational safety and health when he entrusts his duties is a contravention and is sanctioned by a fine of 3,500 to 7,000 lei, according to article 39, paragraph 5 of Law no. 319/2006.

In the absence of a legislative act containing a list of trades and professions to be authorized from the point of view of safety and health at work, employers face real difficulties in meeting the legal requirements listed above, being extremely difficult to cope with the specific legislation governing the licensing of trades and professions.

### 3. The notion of authorization: conceptual clarifications

A major impediment to the identification of trades and professions whose authorization is regulated by specific legislation is also the fact that neither Law no. 319/2006 and nor Government Decision no. 1425/2006 does not define the authorization. This concept is defined only in the specific legislation.

It should also be emphasized that the use of the notion of authorization is not generalized. This notion is used by I.S.C.I.R., A.N.R.E., I.N.S.E.M.E.X. Petroșani and Territorial Labor Inspectorates.

In specific legislation, the activity of assessing the competence and capability of an individual to pursue a trade or profession can also be found under alternative designations of certification or, attestation names that are more or less similar to the notion of authorization. These notions, although not defined in a legal sense, on the basis of the analysis of the specific legislation, can be said to refer to activities to verify the fulfillment of the conditions of professional qualification/specialization and assessment/testing/examination of practical and theoretical knowledge, competence and ability of a person to pursue a specific activity.

The repeal of some normative acts regulating the authorization to practice trades and professions and their non replacement with other normative acts tailored to the needs and expectations of all stakeholders in the field of occupational safety and health generated a lack of regulation or even a „legislative vacuum”. This state of fact has led to the perpetuation, sometimes at the express request of labor inspectors, of anachronistic situations generated by the continued use of some forms of internal authorization which are based on obsolete methodologies or procedures based on the provisions of some repealed normative acts.

It should be underlined that the notion of „internal authorization” has no legal coverage, being a typical Romanian way of adapting of both employers and the controlling authority to a non-compliant but real situation requiring a transitional solution which remained unfortunately final, like any improvisation.

### 4. Authorization of the trades and professions under the specific legislation

As it has already been mentioned, it is extremely difficult to draw up an exhaustive list of trades and professions for which there is specific legislation on the authorization of their exercise in terms of safety and health at work.

The starting point for this approach was the analysis of the current way of regulating the authorization of the trades/professions mentioned in Table 1. Thus, on the basis of a vast documentary study, the existence/non-existence of a legal obligation to authorize the practice thereof was verified for each trade/profession and, if it existed, the applicable specific legislation was identified. In addition to the trades/professions mentioned in Table 1, other trades/professions were identified for which the authorization for their exercise was regulated by specific legislation after the appearance of Order no. 578/DB 5840/1996 of M.M.P.S. and M.S.

The studies and researches carried out have been completed with the drawing up of the list of trades and professions for which it is necessary to authorize their practice from the point of view of safety and health at work, according to the legislation in force. For the drafting of the list, it was chosen to group the trades/professions according to the competent authority. This list is shown in Table 2.

Table 2. List of trades and professions for which authorization to practice them from the point of view of safety and health at work is required

No.	Trade/profession	Legal act	Competent authority
1.	Operator responsible for technical supervision of ISCIR installations/equipment - RSVTI operator	Order no. 130/2011 of I.S.C.I.R.	National Authority for Control and Approval of Boilers
2.	Fireman steam and hot water boilers	Order no. 2154/2009 of M.E.	Pressure Vessels and Hoisting Equipment (I.S.C.I.R.)
3.	Fireman hot water boilers and low pressure steam boilers		



4.	Fireman computer-controlled boilers		
5.	Central heating laboratory operator		
6.	Automatician for boiler supervision and maintenance		
7.	LPG containers filling operator		
8.	Pressure fluid bottler		
9.	Crane operator		
10.	Forklift operator		
11.	Lifter		
12.	Trolley mechanics (funicular operator)		
13.	Manual gas flame welder		
14.	Manual electric arc welder		
15.	Electric arc welder covered under flow layer		
16.	Electric arc welder with fuseable electrode in protective gas medium		
17.	Electric arc welder with non-fuseable electrode in protective gas medium		
18.	Operator welding pipes and fittings made of high density polyethylene (HD-PE)	Order no. 1001/2013 of M.E.	
19.	Non-destructive operator with penetrating radiation		
20.	Non-destructive ultrasound control operator		
21.	Non-destructive operator with penetrating liquids		
22.	Non-destructive operator with magnetic particles		
23.	Non-destructive operator by swirling currents		
24.	Non-destructive operator for leakage check		
25.	Authorized electrician		
26.	Project verifier [electrical installations]	Order no. 11/2013 of A.N.R.E.	National Regulatory Authority for Energy (A.N.R.E.)
27.	Quality technical and extrajudicial expert in the field of electrical installations		
28.	Authorized plumber in the field of natural gas	Order no. 83/2014 of A.N.R.E.	
29.	Construction project verifier	Order no. 2264/2018 of M.D.R.A.P.	Ministry of Regional Development and Public Administration (M.D.R.A.P.)
30.	Technical expert in construction		
31.	Technical manager with construction work	Order no. 1895/2016 of M.D.R.A.P.	State Inspectorate of Construction (I.S.C.)
32.	Transport manager		
33.	Driver (certain categories)		
34.	Safety adviser for the transport of dangerous goods by road		
35.	Driver for the transport of dangerous goods	Order no. 1214/2015 of M.T.	Romanian Road Authority (A.R.R.)
36.	Driver who carries out road transport with vehicles having overhanging masses and/or exceeding dimensions		
37.	Driver who performs road transport by trolleybus		
38.	Driver who performs paid national road transport of damaged road vehicles		
39.	Road safety auditor	Order no. 656/2016 of M.T.	
40.	Lecturer for transport managers		
41.	Lecturer for road law teachers and driving instructors		
42.	Lecturer for the transport of dangerous goods by road	Order no. 1213/2015 of M.T.	Ministry of Transport (M.T.)
43.	Lecturer for drivers		
44.	Safety adviser for the transport of dangerous goods by rail		Romanian Railway Authority (A.F.E.R.)
45.	Safety adviser for the inland waterway transport of dangerous goods	Order no. 1044/2003 of M.T.C.T.	Romanian Naval Authority (A.N.R.) / Romanian Maritime Training Centre (C.E.R.O.N.A.V.)
46.	Personnel working in the field of cold technology (refrigeration technician, installer of ventilation and conditioning installations, personnel operator for working with certain fluorinated gas equipment)	Order no. 2682/2011 of M.M.P.	Romanian General Association for Refrigeration (A.G.F.R.)

47.	Workers carrying out activities with ionizing radiation sources, respectively closed and open radiological installations and radioactive sources	Order no. 202/2002 of C.N.C.A.N.	National Commission for Nuclear Activities Control (C.N.C.A.N.)
48.	Security agent		
49.	Access control agent		
50.	Security agent for enclosures		
51.	Bodyguard agent	Law no. 333/2003 and G.D. no. 301/2012	General Police Directorate of the Municipality of Bucharest (D.G.P.M.B.)/County Police Inspectorates (I.P.J.)
52.	Security and order intervention agent		
53.	Value carrier agent		
54.	Security manager		
55.	Fireworker		
56.	Pyrotechnist	G.D. no. 536/2002	Territorial Labor Inspectorates (I.T.M.)
57.	Mine rescuer		
58.	Rescuer for surface industries		
59.	Control and rescue activity coordination staff	Order no. 1637/391/2007 of M.E.F. and of M.M.F.E.S.	National Institute for Research and Development in Mine Safety and Protection to Explosion - Petroșani (I.N.S.E.M.E.X. Petroșani)
60.	Rescue station mechanic		

## 5. Results and discussion

The comparative analysis of the data and information contained in Table 1 and Table 2 allowed us to highlight the following aspects:

- a number of 13 occupations listed in Table 1 (items 1, 7, 9-11, 14-17, 19-20 and 22-23) are in identical or similar form also in Table 2 (items 2- 5, 9-18, 25, 28, 46-47, 55 and 57-58), representing 56.52 % of the total number of occupations listed in Table 1;
- occupations from items 3 (energy staff for mining blasting gear), 4 (AGR expert), 8 (technical leaders and managers of occupational safety compartments) and 12 (translating mechanics) in Table 1 do not appear in Table 2 because they are not contained in the Classification of Occupations in Romania (COR);
- occupations from items 18 (abrasive body mounting operator) and 21 (technicians and workers performing pre-stressing reinforcement work on concrete prefabricated elements) in Table 1 have not been introduced in Table 2 because they use internal authorization procedures developed on the basis of the provisions of some repealed normative acts and adopted through own instructions for safety and health at work;
- according to the specific legislation in force, for the occupation from item 13 (loaders) in Table 1 the authorization was replaced by the acceptance of the staff and, as a result, this occupation is not found in Table 2;
- occupations from items 2 (underground welding vulcanization, soldering, insulating table casting), 5 (mechanics of extraction machinery) and 6 (signal givers) in Table 1 were not introduced in Table 2 because the specific legislation requiring staff authorization for these occupations was repealed;
- the occupations introduced in addition to Table 2, compared to Table 1, represent:
  - new occupations whose authorization is regulated by specific legislation [e.g., items 1 (RSVTI operator), 6 (automatician for boiler supervision and maintenance), 56 (pyrotechnist), etc.];
  - occupations requiring the attestation or professional certification of personnel for the purpose of their exercise [e.g., road transport specialized staff (items 32-38), security staff and bodyguard (items 48-54), etc.];
  - complementary occupations to those listed in Table 1 [e.g., 60 (rescue station mechanic)].

## 6. Conclusions

Authorizing the exercise of trades and professions from the point of view of safety and health at work has been, is and will remain an extremely problematic issue, proof of which is represented by the increased interest in this issue, which has been manifested lately by the articles posted on various specialized sites and conversations on this topic, often contradictory, on social networks.

Regrettably, despite the topicality of the subject and the importance of this issue, neither the national regulatory authorities nor the occupational safety and health specialists paid not the due attention, which was a major handicap in the drafting of this paper due to the absence of clear and coherent legislative regulations, as well as the extremely low number of bibliographic references.

To overcome this drawback in this paper, a holistic and systemic approach was used, converted in a research methodology that consisted of the following stages:

- the critical analysis of the evolution of national legislative regulations in the field of authorization of the trades and professions from the point of view of safety and health at work, as well as of the current realities and trends in the labor market;

- conceptual clarification and operationalization of the notion of authorization and alternative notions of attestation and certification;
- identification of the professional categories whose authorization/attestation/certification is regulated by specific legislation;
- the description, for each category of staff identified, of the authorization/attestation/certification methodology applied, of the specific requirements imposed (age, seniority, studies, health and fitness conditions, etc.) and the types of acts issued by the main national regulatory authorities with attributions in the field;
- identification of the malfunctions that occur with regard to the authorization of certain trades and professions and establishing, on this basis, the fields of activity for which it is necessary to adopt specific regulations leading to the elimination of these dysfunctions.

Through the information provided, as well as the comments and recommendations formulated, the work has set an ambitious goal, and wants to be a genuine legislative and methodological guide for all interested parties in authorizing the exercise of trades and professions from the point of view of safety and health at work.

The list of trades and professions for which authorization to exercise them from the point of view of safety and health at work proposed in the paper is not and does not claim to be exhaustive. Like any other human creation and this list is also perfectionable and therefore questionable, it is just a starting point, a topic of reflection, which aims to provide the foundation on which to develop a clear and coherent approach to the legislative framework and methodologically in the field of authorization of the trades and professions from the point of view of safety and health at work. As a result, we are inviting and challenging all occupational safety and health specialists to read this paper and to formulate on that basis both critical views and suggestions and recommendations designed to improve its content.

## References

- Băbuț, G.B., Moraru, R.I., Băbuț, M.C., Education and training of professionals in the field of occupational health and safety in the romanian higher education: history, challenges and opportunities, *Quality - Access to Success*, Vol. 11, Issue 11, pp. 48-55, (2010).
- Băbuț, G.B., Moraru, R.I., Occupational risk assessment: imperatives for process improvement, *Quality - Access to Success*, Vol. 19, Issue 166, pp. 133-144, (2018).
- Fuertes, F.C., The formation in professional associations, the lifelong education, the professional authorization and the quality of services aimed at users, *Arbor-Ciencia Pensamiento y Cultura*, Volume 185, pp. 111-124, (2009).
- Furusten, S., Commercialized professionalism on the field of management consulting, *Journal of Organizational Change Management*, Vol. 26, Issue 2, pp. 265-285, (2013).
- Moraru, R.I., Băbuț, G.B., Goldan, T., Popescu-Stealea M., Study on Romanian training requirements needed to develop an occupational safety and health consultant career in the European Union, *Polish Journal of Management Studies*, Vol. 9, pp. 179-189, (2014).
- Pupăzan, D., Călămar, A., Găman, G.A., Kovacs, I., Ilie, C., Importance of mine rescuers vocational guidance and selection process, *Proceedings of the 15th International Multidisciplinary Scientific GeoConference - SGEM 2015*, Volume III, pp. 895-902, Albena, Bulgaria, (2015).
- Ricci, F., Chiesi, A., Bisio, C., Panari, C., Pelosi, A., Effectiveness of occupational health and safety training: A systematic review with meta-analysis, *Journal of Workplace Learning*, Vol. 28, Issue 6, pp. 355-377, (2016).
- Tappura, S., Teperi, A.-M., Kurki, A.-L., Kivistö-Rahnasto, J., The management of occupational health and safety in vocational education and training, *Advances in Intelligent Systems and Computing*, Vol. 785, pp. 452-461, (2019).

## Improving drained gas quality parameters through optimal management of methane drainage systems

Băbuț Gabriel Bujor<sup>a,\*</sup>, Moraru Roland Iosif<sup>a</sup>, Popescu-Stelea Mihai<sup>a</sup>, Băbuț Andrada Denisa<sup>b</sup>

<sup>a</sup>University of Petroșani, University Street, no. 20, 332006-Petroșani, Romania

<sup>b</sup>National Institute for Research and Development in Mine Safety and Protection to Explosion-INSEMEX, no. 32-34, G-ral Vasile Milea Street, 332047-Petroșani, Romania

---

### Abstract

Sustainable exploitation of coal in Jiu Valley can not be achieved without using methane drainage systems, given that the primary objective of these is to improve the safety and health of workers and ensure the proper environmental conditions underground, by reducing the concentration of methane in the mine atmosphere. It should not be neglected the valorization of drained gas which can play an important role in increasing the efficiency and profitability of mines. Studies and research on improving the efficiency of degassing coal seams in Jiu Valley focused, in particular, on the development of automated monitoring and management system for methane drainage networks. Despite progress achieved, qualitative and quantitative parameters of drained gas are still hard to keep under control due to inadequate knowledge about the phenomena related to migration of gas from massive to boreholes. Currently, the location of boreholes and setting the amount of depression on the borehole so that the highest possible gas flow to be captured is an area with prevailing empirical approaches that do not always achieve the objectives set. From this perspective, this paper aims to present, based on current the situation analysis, an original mathematical model of boreholes location for achieving an optimal management of methane drainage systems.

**Keywords:** methane drainage; borehole; coal; optimisation; quality; management;

---

### 1. Introduction

In order to increase the efficiency coal seam drainage in the Jiu Valley, studies and research carried out so far have focused on optimizing the design and operation of methane drainage systems, in this regard the following areas of research being outlined (Băbuț et al., 2018):

- development of a mathematical model and software for simulation of methane drainage systems (Băbuț and Moraru, 2017);
- development of an automated monitoring and management system for methane drainage networks (Băbuț and Moraru, 2014);
- development of an expert system for the analysis of methane drainage systems.

Studies in the first two areas of research are completed, the practical implementation of their results in the Jiu Valley mining units being conditioned by providing human, financial and material resources required. The third area of research is in an early stage of development, studies still being needed in this field.

Unfortunately, despite progress made in terms of simulation and automatic control of methane drainage networks, qualitative and quantitative parameters of drained gas are still hard to keep under control due to inadequate knowledge about the phenomena of gas migration massif towards the boreholes (Băbuț et al., 2017).

In conclusion, we can say that improving qualitative and quantitative parameters of the drained gas can not be achieved only through:

- critical analysis of the framework drainage schemes currently used in mines within the Jiu Valley;
- determination of the influence exerted on the drainage process efficiency by the drainage boreholes spatial distribution, their geometrical features, as well as the distance from the boreholes to the working face;

---

\* Corresponding author. Tel.: +40 732 971 484; fax: +40 254 543 491.  
E-mail address: gabriel\_babut@yahoo.com.

- determining the value of the pressure drop on the borehole so that the captured gas flow to be as high as possible, for given characteristics of the vacuum pump.

From this perspective, the paper aims to present an original mathematical model for the location of boreholes enabling the optimization of degassing according to targets set by decision - makers.

## 2. Coal seam drainage through boreholes drilled in underground locations

Capturing methane through boreholes drilled in the underground is, like on worldwide level, the most used method (sometimes only) used for degassing coal seam from mines in the Jiu Valley coal basin.

The location of drainage boreholes, the parameters, how to achieve them, and their arrangement are determined in accordance with the "Drainage Project" (N.H.C.C., 2007). The drainage project is drawn by the ventilation - health and safety at work department, approved by the chief engineer of safety and health at work, also approved by the head of the branch, endorsed by the Department of Occupational Safety and Health at Work in the Hunedoara Energy Complex - S.A. and finally approved by a certified body (NIRD-INSEMEX Petroșani).

The position of the drainage boreholes and their inclinations and directions are checked by the supervisor of the drainage activity. Drainage boreholes are cased and cemented on a minimum length of 6 m and equipped with control valves and fittings. According to the sealing method used the drainage boreholes may be performed in two ways: the technique with concentric piping and the technique with the pneumatic fastener.

With the exception of these two techniques, in the Jiu Valley collieries there have been experimented also other methods, of which are to be mentioned the method to support the drainage boreholes along their length with the perforated metal columns in the last 10 m toward the base. This technique which prevents the destruction and shear of the borehole gave superior results to those obtained by the conventional methods, but because it is more expensive it was not introduced into current practice.

Drainage schemes which may be applied to Jiu Valley collieries, by type of structure and mining methods used are those contained in "Occupational Safety and Health Regulation of National Hard Coal Company - Petroșani" (N.H.C.C., 2007). In Table 1 are shown the geometrical characteristics of boreholes for drainage framework schemes applied in Jiu Valley collieries.

Table 1. Geometrical characteristics of boreholes for drainage framework schemes applied in Jiu Valley collieries

No.	Characteristics	UM	Value ranges of characteristic parameters in drainage framework schemes applied in Jiu Valley collieries								
			"A"	"B"	"C"	"D"	"E"	"F"	"G"	"H"	"I"
1.	Tubing-cementing diameter of the borehole	mm	100-125	100-125	100-125	100-125	100-125	100-125	100-125	100-125	100-125
2.	Tubing-seal-cementing length	m	6-10	6-10	6-10	6-10	6-10	6-10	6-10	6-10	
3.	Number of boreholes in a location	pieces	1-2	depending on the panel length	2-6	4-6	4-8	1	2	9-16	5-10
4.	Borehole diameter	mm	65-86	65-86	65-86	65-86	65-86	65-86	65-86	65-86	65-86
5.	Borehole length	m	20-40	60-100	60-100	60-100	60-100	60-100	60-100		
6.	Borehole's angle of inclination ( $\alpha_g$ )	(°)	2°-4°	-	$\alpha_{2,4}=0^\circ$ $\alpha_3=10^\circ$ $\alpha_{1,5}=15-20^\circ$	based on relation $H-h=4 \cdot i_a$	10°-20°	$\alpha_q = \alpha_s$	$\alpha_q = \alpha_s$	$\alpha_1=10^\circ$ $\alpha_2=15^\circ$ $\alpha_3=25^\circ$	$\alpha_q < 10^\circ$
7.	Borehole's angle of direction ( $\beta_g$ )	(°)	0-45°	10°	0-10°	40°-120°	45°-125°	90°	90°±10°	0-90°	0-90°
8	Distance between the adjacent boreholes base	m	-	-	10	10	10	-	-	10	10

## 3. The current state of knowledge in the borehole characteristic determination field

Solving properly a methane drainage networks is more difficult than solving a mine ventilation network. The concept of resulting characteristic can only be applied to solve the ventilation systems, it can not be used for all the elements of methane drainage networks, given that these are more complex, consisting of three components having different characteristics: borehole - piping drainage system - vacuum pump. The borehole characteristic is the dependence between depression/pressure drop in the borehole and the gas flow exhausted from it.

Determination of the borehole characteristic represented the study subject for an important number of researchers. Thus, in a first stage, the high-scale coal seams drainage systems has been accompanied by the development of studies and research aimed at establishing empirical relationships describing the characteristic of the borehole. Empirical

relationships presented in the literature due to certain coefficients difficult to determine and to geological/mining conditions are difficult to use for analyzing efficiency of various schemes of boreholes location and drainage regime optimization.

Currently, benefiting from the advantages of using advanced informatics tools, research efforts made worldwide have targeted the following aspects:

- establishing the influence of the boreholes length and their applied depression to the qualitative and quantitative parameters of the drained gas (Chen et al., 2017);
- determining the effectiveness for methane emissions reduction of various schemes of boreholes location, taking into account in particular the influence of boreholes length and degassing time before and during panels (Karacan et al., 2007; Karacan et al., 2011);
- assessing the effect on the methane reduction efficiency of the distance from the first borehole at the working face in the specific case of the U ventilation system (Berger et al., 2010.);
- developing software applications for the study and analysis of operation of boreholes used for methane (Serdyukov et al., 2017);
- determining the effect of pressure drop applied on the boreholes upon the qualitative and quantitative parameters of captured gas and establishing adjustment procedures aimed at increasing the drainage efficiency of coal seams (Liu et al., 2018);
- optimization of the borehole length to maximize gas drainage (Zhang et al., 2018; Zhao et al., 2018);
- determining optimal parameters of the methane drainage system to reduce the methane concentration in the atmosphere of mine workings (Khodyrev, 2008; Ren et al., 2001);
- numerical analysis of horizontal boreholes location to reduce methane emissions in the mine atmosphere and increase the amount of coal extracted (Keim et al., 2011).

Analysis of the current state of knowledge in determining the borehole characteristic shows that the majority of studies and researches have considered only some of the parameters that influence the dependence of depression/pressure drop on the borehole and the drained gas flow thereof; it does not exist at the present time a mathematical model which takes into account all the parameters which determines the coal seams drainage efficiency, respectively the spatial distribution of boreholes, geometric characteristics thereof (length, cased length, diameter, angle of inclination), and the distance from boreholes to the working face.

Given the above, it will now be presented a mathematical model that will try to correlate all the parameters listed above to improve qualitative and quantitative parameters of drained gas.

#### 4. Mathematical modeling of the boreholes location

Theoretical and experimental research carried in Jiu Valley coal basin (Moraru et al., 2013; Moraru and Băbuț, 2014; Moraru et al., 2016) and abroad (Balla, 1989; Ding et al., 2008; Pawiński et al., 1996; Zheng et al., 2016) have shown that the flow rate of a borehole can be expressed using the relationship:

$$Q_s = c_0 + c_1 \cdot x + c_2 \cdot x^2 + c_3 \cdot x^3 + c_4 \cdot h_s + c_5 \cdot h_s^2 \quad (1)$$

where:

$Q_s$  is the borehole flow rate, m<sup>3</sup>/s;

$h_s$  - depression, N/m<sup>2</sup>;

$c_0, \dots, c_5$  - the regression equation coefficients, determined from statistical processing of experimental data;

$x$  - length from the borehole to the working face, m.

Equation (1) can be used to calculate the flow rate of a borehole, when the parameters  $x$  and  $h_s$  are known. When a number of simultaneously operating boreholes  $n_s$ , the total flow rate of the boreholes can be expressed by the equation:

$$\sum Q_s = \left[ n_s \cdot (c_0 + c_4 \cdot h_s + c_5 \cdot h_s^2) + c_1 \cdot l \cdot \frac{n_s - 1}{2} + n_s \cdot x + c_2 \cdot \sum_{i=0}^{n_s-1} (x + i \cdot l_s)^2 + c_3 \cdot \sum_{i=0}^{n_s-1} (x + i \cdot l_s)^3 \right] \cdot k_s \quad (2)$$

where:

$l$  is the distance on which the boreholes are drilled, m;

$n_s$  - the number of simultaneously operating boreholes;

$l_s$  - the distance between the boreholes, m;  $l_s \cdot n_s = 1$ ;

$k_s$  - coefficient assessing the simultaneous operation of boreholes;

$x$  - the distance from the first borehole to the face, m.

The coefficient  $k_s$ , of simultaneous operation of two or more boreholes can be calculated with sufficient precision, with the the relation:

$$k_s = d_0 + d_1 \cdot n_s + d_2 \cdot l_s \quad (3)$$

where:  $d_0, d_1, d_2$  are the regression equation coefficients.

If in the equation (2) is used the equality  $x = l_s$ , it can be used as an objective function to determine the optimum values of the number of boreholes and the distance between them, values that will deliver a maximum drained flow rate. The optimization problem can be solved using the method of the alternatives; the calculation results can be presented graphically or tabular. This problem's solution is simplified by using the substitution  $l_s = l/n_s$ .

Using the relation (2) we can determine the required number of boreholes, for a total drained flow rate  $\Sigma Q_s$ . In this case, equation (2) can be put in the form of:

$$D_0 + D_1 \cdot n_s + D_2 \cdot n_s^2 + D_3 \cdot n_s^3 + D_4 \cdot n_s^4 + D_5 \cdot n_s^5 - \Sigma Q_s = 0 \quad (4)$$

The values of the coefficients  $D_0, D_1, D_2, D_3, D_4, D_5$  are obtained by transforming the equation (2), taking into account equation (3). Equation (4) can be solved using numerical calculation methods. Since the solution to this equation is not an integer, the result is adopted as the next whole number to the solution obtained by computation.

## 5. Drainage regime optimization

For the optimization of the quasi-stationary drainage regime it is necessary to assess the total flow of boreholes for the entire duration of their operation. Solving the problem can be simplified if we accept the hypothesis of replacement of two boreholes changing each other (the second borehole connects to the drainage network when decoupling the first borehole), with a borehole having doubled operating time.

The flow variation rate in the case of the use of said type of borehole may be represented by a curve with two points of maximum flow rate:

$$Q_{s0} = c_0' + c_1' \cdot x + c_2' \cdot x^2 + c_3' \cdot x^3 \quad (5)$$

where:  $c_0', c_1', c_2', c_3'$  are the regression equation coefficients.

Conventional borehole flow rate dependence of distance for a given value of the depression may be expressed in the form of a trigonometric series:

$$Q_{s0} = a_0 + \sum_{k=1}^N a_k \cdot \cos(k \cdot \pi \cdot x \cdot l^{-1}) + \sum_{k=1}^{N-1} b_k \cdot \sin(k \cdot \pi \cdot x \cdot l^{-1}) \quad (6)$$

where:  $a_0, a_k, b_k$  are the trigonometric series coefficients.

To determine the coefficients  $a_0, a_k, b_k$  it can be used an approximate alternative of the harmonic analysis, respectively the 12 ordinate method. The range of length  $2 \cdot l$  is divided into 11 equal parts, and the flow is divided into 12 points (12 ordinates) and is determined by the relationship (5). In general, the determination of the borehole's flow rate using the relationship (5) is done for a minimum value of the depression.

The individual flow rate of a borehole, taking into account the value of the depression at the entry of the borehole, will be given by:

$$S_0 = S_{s0} + A_1 \cdot (h_s - h_{sm}) + A_2 \cdot (h_s - h_{sm})^2 \quad (7)$$

where:  $h_{sm}$  is the value of the depression at the entry of the borehole for which the values given by the relation (6) were obtained.

To obtain coefficients  $A_1$  and  $A_2$ , equation (1) can be used. For this purpose, it is necessary to calculate the value of the flow for a fixed value of the distance from the borehole to the face and for different values of the depression and to repeat these calculations several times, for different values of the distance from the borehole to the working face.

The total flow of the boreholes running simultaneously can be described by the relationship:

$$\begin{aligned} \Sigma Q_s = & a_0 \cdot n_s + \sum_{k=1}^6 a_k \sum_{j=0}^{n_s-1} \cos[k \cdot \pi \cdot (x + j \cdot l_s) \cdot l^{-1}] + \sum_{k=1}^5 b_k \sum_{j=0}^{n_s-1} \sin[k \cdot \pi \cdot (x + j \cdot l_s) \cdot l^{-1}] + \\ & + A_1 \sum_{j=0}^{n_s-1} (h_0 - h_{sm} - j \cdot p_{sf} \cdot l_s) + A_2 \sum_{j=0}^{n_s-1} (h_0 - h_{sm} - j \cdot p_{sf} \cdot l_s)^2 \end{aligned} \quad (8)$$

where:

$h_0$  is the depression at the first borehole level,  $N/m^2$ ;

$p_{sf}$  - the specific pressure loss due to frictional resistance,  $N/m^2$ .

To optimize the quasi-static drainage mode, the following objective functions can be used (Băbuț et al., 2018):

$$l + 0,5 \cdot \int_0^l \left( \frac{d \Sigma Q_s}{dx} \right)^2 dx \rightarrow \min. \quad (9)$$

$$l^{-1} \cdot \int_1^l \left\{ \left| \left( \sum Q_s \right)'' \right| \cdot \left\{ 1 + \left[ \left( \sum Q_s \right)' \right]^2 \right\}^{\frac{3}{2}} \right\} dx \rightarrow \min. \quad (10)$$

## 6. Conclusions

Increasing the efficiency of coal bed degassing and implicitly improving the qualitative parameters of captured gas can not be obtained without a thorough knowledge of the dependence between the depression/pressure drop at the borehole and the exhausted gas flow from there.

In order to contribute to solving this problem, for the geological and mining conditions specific to the Jiu Valley mines, a research methodology has been used in the paper which involves going through the following stages:

- description of the methods and procedures for achieving the drainage of coal strata through underground drilling boreholes, specifying the geometrical characteristics of the boreholes for the drainage frame schemes used in the Jiu Valley mines;
- the analysis of the current state of knowledge in the field borehole characteristics determination, based on a comprehensive documentary study;
- the development of an original mathematical model for the location of the boreholes to allow optimization of the drainage regime.

Unfortunately, the lack of resources required to carry out experimental studies have given the research presented in the paper a preponderantly theoretical character, the research objectives envisaged being only partially fulfilled. Thus, it can be mentioned that a critical analysis of the drainage schemes used in the Jiu Valley mines could not be carried out, which further determined the impossibility of assessing the influence it exerts on the drainage, efficiency of the spatial distribution of the boreholes, their geometrical characteristics, and the distance from the boreholes to the working front. Also, the validity of the mathematical model proposed in the paper could not be verified by experimental studies.

Despite these limitations, it can be argued that the mathematical model proposed in the paper for the simulation and optimization of the borehole location represents a modern and original approach to this problem, which attempts to correlate the vast majority of the parameters that exert influence on the efficiency of the coal seam drainage.

The use of the mathematical model presented in the paper allows the calculation and optimization of the main parameters of the drainage of coal seams through boreholes and can contribute, by reducing the methane emissions in the atmosphere of the mining works both to improving the safety and health of the workers, and to increasing the degree of valorization of drained gas and extracted output.

## References

- Balla, L., Mathematical modeling of methane flow in a borehole coal mining system, *Transport in Porous Media*, Vol. 4, Issue 2, pp. 199-212, (1989).
- Băbuș, G.B., Moraru, R.I., Automated monitoring and management system for methane drainage networks operated in Jiu Valley collieries, *14th International Multidisciplinary Scientific GeoConference - SGEM 2014*, Vol. 3, Issue 1, pp. 71-78, Albena, Bulgaria, (2014).
- Băbuș, G.B., Moraru, R.I., Algorithm and software development for optimal management of methane drainage system at Lupeni colliery, *17th International Multidisciplinary Scientific GeoConference - SGEM 2017*, Vol. 17, Issue 13, pp. 31-38, Albena, Bulgaria, (2017).
- Băbuș, G.B., Moraru, R.I., Popescu-Stelea, M., Means to improve underground coal mine safety by automated control of methane drainage systems, *MATEC Web of Conferences*, Vol. 121, Article Number 11005, (2017).
- Băbuș, G.B., Moraru, R.I., Popescu-Stelea, M., Analysis of ways to optimize the design and operation of methane drainage systems, *18th International Multidisciplinary Scientific GeoConference - SGEM 2018*, Vol. 18, Issue 1.3, pp. 111-118, Albena, Bulgaria, (2018).
- Berger, J., Markiewicz, J., Dolega, T., Influence of distance of exploitation front from drainage boreholes on their efficiency with use the U ventilation system, *Archives of Mining Sciences*, Vol. 55, Issue 3, pp. 561-571, (2010).
- Chen, Y., Xu, J., Peng, S., Feng, D., Zhang, C., Computational model and time-space evolution of gas pressure for different borehole lengths in coalbed methane drainage, *Journal of Geophysics and Engineering*, Vol. 14, Issue 3, pp. 586-598, (2017).
- Ding, H.a, Jiang, Z., Han, Y., Numerical simulation and application of boreholes along coal seam for methane drainage, *Journal of University of Science and Technology Beijing*, Vol. 30, Issue 11, pp. 1205-1210, (2008).
- Karacan, C.Ö., Diamond, W.P., Schatzel, S.J., Numerical analysis of the influence of in-seam horizontal methane drainage boreholes on longwall face emission rates, *International Journal of Coal Geology*, Vol. 72, Issue 1, pp. 15-32, (2007).
- Karacan, C.Ö., Ruiz, F.A., Cotè, M., Phipps, S., Coal mine methane: A review of capture and utilization practices with benefits to mining safety and to greenhouse gas reduction, *International Journal of Coal Geology*, Vol. 86, Issue 2-3, pp. 121-156, (2011).



- Keim, S.A., Luxbacher, K.D., Karmis, M., A numerical study on optimization of multilateral horizontal wellbore patterns for coalbed methane production in Southern Shanxi Province, China, *International Journal of Coal Geology*, Vol. 86, Issue 4, pp. 306-317, (2011).
- Khodyrev, Y., Determination of methane drainage borehole system optimal parameters to decrease gas content in mine workings, *8th International Scientific Conference on Modern Management of Mine Producing, Geology and Environmental Protection - SGEM 2008*, Vol. 1, pp. 277-280, (2008).
- Liu, ZD., Cheng, YP., Dong, J., Jiang, JY, Wang, L., Li, W., Master role conversion between diffusion and seepage on coalbed methane production: Implications for adjusting suction pressure on extraction borehole, *Fuel*, Vol. 223, pp. 373-384, (2018).
- Moraru, R.I., Băbuț, G.B., Cioca, L.I., Study of methane flow in caved goafs adjacent to longwall faces in Valea Jiului coal basin, *13th International Multidisciplinary Scientific Geoconference - SGEM 2013*, Vol. I, pp. 731-738, Albena, Bulgaria, (2013).
- Moraru, R.I., Băbuț, G.B., Research on methane emission mechanism and pattern in a longwall coal face at Livezeni colliery, *14th International Multidisciplinary Scientific Geoconference - SGEM 2014*, Vol. III, pp. 497-504, Albena, Bulgaria, (2014).
- Moraru, R.I., Băbuț, G.B., Popescu-Stelea, M., Field test results and prerequisites for methane build - up simulation in longwall face goafs, *16th International Multidisciplinary Scientific GeoConference - SGEM 2016*, Vol. II, pp. 405-412, Albena, Bulgaria, (2016).
- N.H.C.C., Occupational Safety and Health Regulation of National Hard Coal Company - Petroșani (in Romanian), National Hard Coal Company, Petroșani, Romania, (2007).
- Pawiński, J., Roszkowski, J., Szlązak, N., 1996. Determining the parameters impacting the intensity of the flow of methane in drainage boreholes, *Archives of Mining Sciences*, Vol. 41, Issue 1, (1996).
- Ren, T.X., Edwards, J.S., Whittles, D., Reddish, D.J., Firedamp drainage optimization using geotechnical and CFD modelling techniques, *29th International Symposium on Computer Applications in the Mineral Industries*, pp. 549-554, Beijing, China, (2001).
- Serdyukov, S.V., Patutin, A.V., Shilova, T.V., Borehole tool for studies in coalbed degasification wells, IOP Conference Series: Earth and Environmental Science, Vol. 53, Issue 1, Article number 012029, (2017).
- Zhang, C., Xu, J., Peng, S., Li, Q., Yan, F., Chen, Y., Dynamic behavior of gas pressure and optimization of borehole length in stress relaxation zone during coalbed methane production, *Fuel*, Vol. 233, pp. 816-824, (2018).
- Zhao, D., Liu, J., Pan, J.T., Study on gas seepage from coal seams in the distance between boreholes for gas extraction, *Journal of Loss Prevention in the Process Industries*, Vol. 54, pp. 266-272, (2018).
- Zheng, C., Chen, Z., Kizil, M., Aminossadati, S., Zou, Q., Gao, P., Characterisation of mechanics and flow fields around in-seam methane gas drainage borehole for preventing ventilation air leakage: A case study, *International Journal of Coal Geology*, Vol. 162, pp. 123-138, (2016).

## Management of electrical equipment and protective devices used in electrical installations

Georgeta Buică<sup>a\*</sup>, Anca Elena Antonov<sup>a</sup>, Constantin Beiu<sup>a</sup>,

Dragoş Pasculescu<sup>b</sup>, Mircea Risteiu<sup>c</sup>

*INCDPM “Alexandru Darabont”, 35A Blvd Ghencea, 6<sup>th</sup> county, Bucharest 062692, Romania  
University of Petrosani, 20 Universităţii st., Petrosani 332006, Hunedoara, Romania,  
University “1 Decembrie 1918” Alba-Iulia, Romania*

---

### Abstract

The use of working equipment and means of protection is a technical safety measure used against electrical hazards during the operation and maintenance of electrical installations. The study presents the results of the research on the identification of the technical and safety requirements specific to a category of protective equipment - the insulating sticks. They are designed to provide a safety distance during the maintenance of electrical installations. The identification of the technical and safety requirements allowed the testing of new and used electrical insulating sticks for assessing and attesting the technical and safety performance during their use.

The behaviour of this category of equipment has been assessed at mechanical, thermal and electrical requirements in order to identify changes or deflection from the normal technical and functional characteristics.

The technical and safety requirements applicable to insulated electrical sticks are intended to provide the criteria underlying the management of the protective equipment required by both manufacturers and users in order to adopt high-tech and safety solutions to ensure their compatibility with electrical installations and to ensure the safe maintenance of these working equipment.

*Keywords:* risk, safety, work equipment, insulating electrical sticks, management;

---

### 1. Introduction

One of the most important objective at national level is to ensure the conditions for the competitiveness of the producers of work equipment on the market and to guarantee the free circulation of Romanian products within the European Union (EU), considering Romania as a member state, by ensuring the technical and health and safety requirements applicable to all work equipment, in order to implement the policies provided by the free movement of products contained in the EUROPA 2020 strategy. (Antonov et al, 2017)

As a consequence of the need to ensure compliance with the safety and health requirements set out in Annex 1 of Directive 2009/127/EC, and Directive 2014/35/EU, the research study focuses mainly on the analysis undertaken to identify the technical requirements and safety features specific to a category of protective equipment, in order to increase the compliance rate of work equipment in use, according to new manufacturing technologies and the methods used are:

- Identifying the safety and technical requirements applicable to electrical insulating sticks, which are within work equipment category, and which is the subject of the project analysis;
- Establishing the health and safety requirements applicable to electrical insulating sticks, according to the legal provisions set out in Annex no. 1 of Executive Order (EO) no.1146/2006, which adopts European Directive no. 2009/104/EC (Work equipment directive);
- Establishing the health and safety requirements applicable to electrical insulating sticks, in accordance with the legal provisions set out in Annex 1 of the EO no.409/2016, which adopts the Machinery Directive no. 2014/35/EU (Electrical Equipment Design Directive);

---

\* Corresponding author. Tel.: 0213131729/int 209; fax: 0213157822.

E-mail address: gbuica@protectiamuncii.ro.

- Establishing the health and safety requirements applicable to electrical insulating sticks, according to the legal provisions set out in the specific safety standards analysed in the project.

The electrical equipment and protective devices can be evaluated using the quality function deployment (QFD) method. This provides the tools to evaluate by an overall index the correlation between the customer requirements and the quality characteristics (Leba M., et al, 2014).

Insulating sticks are work equipment that provides protection of workers against the electrical hazards, by providing an insulation level that is required to safely perform live or dead working.

Insulating sticks consist of one or more hollow tubes and / or filled with foam fitted with couplings between them and at the head, in order to attach accessories and / or various types of work equipment. In use, we also identified insulating sticks for round bars.

The insulating sticks have an insulating element and a handle separated by a hand guard made of insulating material that must be shockproof, with a larger diameter than the handle. For technical reasons, the bottom of the insulating rod is provided with a cap.

In electrical installations, insulating sticks can be used to carry out a series of operations by means of attached working equipment or accessories, such as: (SR EN 50508, 2009), (SR EN 62193, 2004), (Buica, 2010)

- Verifying the presence / absence of voltage by using the attached voltage detector or the single phase systems with the monopolar indicators;
- Earthing and short-circuiting by mounting earth and short-circuit mobile devices;
- Capacitive load discharge;
- Mounting rigid or flexible protectors on live parts of electrical installations that can be reached during maneuvers or work;
- Performing electrical operations (connection and disconnection of disconnectors or other equipment operated by the insulating sticks, fuse replacement with an attached tool, testing and measurement, lifting of signal flaps mounted on electric cables);
- Removal of foreign objects from or near live parts;
- Removal of victims from or near live installations.

## 2. Analysis and evaluation of insulating sticks used in electrical installations

Identifying, analysing and assessing the risks of injury and occupational disease generated by work equipment are the basic tools of risk management to reduce and eliminate by technical and organizational measures. The benefit of risk assessment allows identification of the problems faced by users, which requires the adoption of preventive measures (Antonov et al., 2016).

The study has as its starting point the analysis and evaluation of electrical insulating sticks used in electrical installations for transport, distribution and use of electric energy. Various categories of insulating sticks have been identified: simple, made of removable or telescopic insulating modules, components of earthing or earthing and short-circuiting devices.

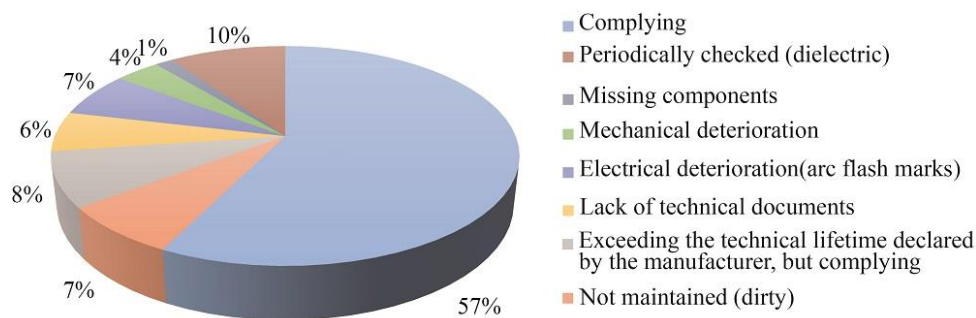


Fig. 1. Percentage results on the evaluation of insulating sticks in use.

Fig. 1 shows the percentage of the technical condition and the conformity of the insulating sticks in use. The insulating sticks from 17 high-voltage electric power stations (400, 220, 110, 20, 6 kV), 9 hydropower plants and micro-hydro power plants, 1 wind farm and 3 economic operators were analysed.

In this respect, we analysed and evaluated:

- Technical state of insulating sticks (inspection by visual inspection), mode of use, storage mode;
- Compatibility with the electrical system in which it is used;
- The existence and content of the technical documentation of the pairs and the documents attesting to their compliance certification;
- The existence and content of periodic inspection reports (dielectric rigidity);

- Documents on risk management generated by these working equipment.

Based on the evaluation of the technical condition, the existence and the content of the technical documents (technical instructions for use, periodic inspection reports) it was found out that from the total of working equipment evaluated: 57% meet the criteria established in the evaluation, do not show technical nonconformities, have technical documents; 10% of the working equipment has technical documentation, it is tested periodically but it was dirty; 4% of the insulating sticks had no technical documents but were in compliance; 28% of the insulated sticks evaluated were identified as non-compliant. From this percentage, 8% had missing components; 7% had traces of flashovers and arc flashes; 6% were mechanically damaged (cracks, scraps, damaged hand guard).

The risk management of protective equipment and insulating sticks has been analyzed through the existence and content of management documents, which employers have to develop, hold and operationalize. The following was analyzed:

- Technical safety and health data sheets for the purchase of insulating sticks;
- Instructions for use / technical books;
- Procedures for testing the protective equipment or insulating sticks in use;
- Annual plans for testing the protective equipment in use;
- Checking registers, according to art. 5 of EO no. 1146/2006;
- Type verification reports and periodic verification reports.

The analysis of the management documents showed the following data, presented in fig. 2 (percent).

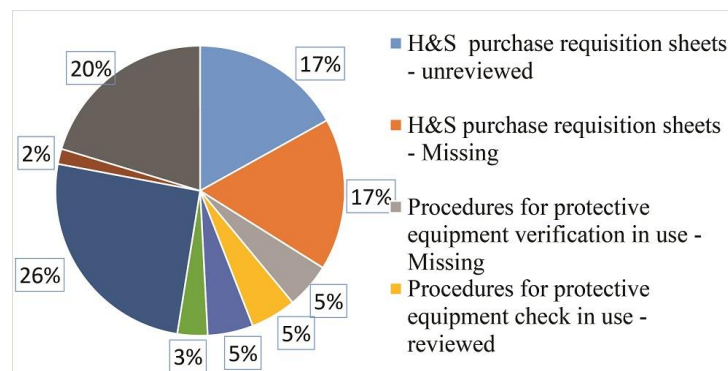


Fig. 2. Results on analysis of management documents

It is noted that in some companies' management the documents of specific risk generated by the protective equipment are partially completed or totally missing. This situation can become a negative determinant regarding the monitoring of safety quality of work equipment in use, and may contribute to generation of work accidents, complementary to the specific risk factors for the occurrence of technical events in electrical installations. Improving safety conditions through more efficient management of risks generated by safety equipment can be achieved through the effective involvement of top management, decision-makers and health and safety department, in conjunction with the concrete implementation of specific management documents.

Risk management generated by protective equipment, as well as the occupational health and safety management system are the key component which has to be integrated in the company's general management system and its implementation should be made by integration in other management systems which are relevant for the organization, such as quality, environment or social responsibility. (D. Darabont et. al., 2017).

### 3. Technical and safety requirements applicable to insulating sticks

In order to ensure the use of safe working equipment, the designer and the manufacturer must certify the compliance with the national and European provisions and standards, national technical regulations, users' health and safety documents (their own Health and Safety Instructions for workers) and good practice (Antonov et al., 2017).

For this purpose, the insulating sticks must meet the requirements laid down in EO no.1146/2006 on minimum safety and health requirements for the use of work equipment by workers; safety objectives / assimilated requirements of the EO no. 409/2016 laying down the conditions for making available on the market of low voltage electrical equipment that adopt the provisions of Directive 2014/35/EU.

The conditions of use (field of use, precautions in use, maintenance, storage and transport conditions) and the technical characteristics (dimensional, mechanical, electrical and thermal properties) were taken into account in determining the technical and safety requirements applicable to insulating sticks, corroborated with the results of the analysis and evaluation of insulating sticks in use. Table 1 presents the minimum technical and safety requirements applicable to insulating sticks (Buica, 2010).

Table 1. Technical and safety requirements applicable to insulating sticks

S/N	Technical and safety requirements on work equipment	Legal provision		Testing condition		
		EO no. 1146/2006	EO no. 409/2016	SR EN 50508	SR EN 60832	SR EN 62193
1.	Component materials, insulating hollow tubes	-	-	SR EN 60855, SR EN 61235		
2.	Visual inspection, dimension	-	-	5.3.1, 5.3.2	5.2, 5.3	6.2.1, 6.2.2
3.	Test of fitting and removal of tools attached to the head	-	1b	5.4.4	-	-
4.	Wear test	3.3.1.2a	3a	-	-	6.5.5
5.	Mechanical test	3.3.1.2a	3a	-	5.5	-
	• Bending test	3.3.1.2a	3a	5.4.1	5.5.5	6.5.1
	• Torsion test	3.3.1.2a	3a	5.4.2	5.5.2	6.5.4
	• Pulling test	3.3.1.2a	3a	5.4.3	5.5.3	6.5.3
	• Drop resistance	3.3.1.2a	3a	5.4.5	-	6.5.2
	• Shock resistance on couplings	3.3.1.2a	3a	5.4.6	-	-
	• Abrasion resistance	3.3.1.2a	3a	-	-	-
	• Pulling test on hand guard	3.3.1.2a	3a	-	-	-
6.	Electrical test	3.3.1.1	2a, 2b, 2d	-	5.7	6.4.2
	• Leakage current test	3.3.1.1	2a, 2b, 2d	5.2.2	-	-
	• Bridging test	3.3.1.1	2a, 2b, 2d	5.2.3	5.7.2	-
	• Dry	3.3.1.1	2a, 2b, 2d	-	-	-
	• Extreme temperature condition	3.3.1.1, 3.3.1.2b	2a, 2b, 2d, 3b	-	-	-
	• Raining conditions	3.3.1.1, 3.3.1.2b	2a, 2b, 2d, 3b	-	-	-
	• Electrical test after water conditioning	3.3.1.1, 3.3.1.2b	2a, 2b, 2d, 3b	-	5.7.1	-
7.	Chemical test	-	-	-	-	-
	• Resistance to solvents	-	-	-	-	-
	• Resistance to penetration of the paint	-	-	-	5.6	-
8.	Testing the hydrophobic surface properties	3.3.1.2b	3b	-	-	6.4.1
9.	Environment test	-	-	-	-	-
	• Extreme temperature condition	-	-	-	-	-
10.	Water penetration test	3.3.1.1, 3.3.1.2b	2a, 2b, 2d, 3b	5.2.4	-	-
11.	Corrosion resistance of metal heads and accessories of insulating stick	3.3.1.2b	3b	-	-	-
12.	Marking	-	1a	5.3.5	5.4	6.3

For technical and safety requirements which test conditions and methods have not been identified for, testing methods have been developed.

Testing methods have been validated by testing several new and in use insulating sticks from different manufacturers.

In this study, in order to certify the, technical quality and safety performances of the insulating sticks, 6 models of new insulating sticks (42 specimens) were evaluated and tested for chemical, electrical, mechanical and thermal properties, in order to identify changes or deviations from the technical characteristics and normal operation.

Two models of telescopic insulating sticks, 6 insulating sticks made of modules, but with different coupling systems and 2 simple insulating sticks models were tested. All 6 models are used in electrical installations with rated voltages between 6 and 400 kV. Other 36 insulating sticks, already in use, were also evaluated and tested.

The new equipment batches were subjected to the requirements specified in table 1, depending on the field of use, the technical characteristics and the manufacturer's specifications, based on logical schemes for the application of the procedure for the assessment and diagnosis of the safety of work equipment and the means of protection.

Based on the technical and safety requirements applicable to insulating sticks, additional tests have been proposed and verification methods have been developed. In order to verify the dielectric characteristic in use, mechanical, chemical, thermal, climatic and dielectric tests have been performed.

Microclimate conditions can decisively influence the safety of insulating working equipment, in terms of insulation degradation, which leads to a high risk for workers. (Pasculescu, V. M. et al., 2016).

To prevent this risk, additional requirements have been imposed and / or verification procedures have been developed and applied by testing on a part of the specimens. The requests for environmental conditions were performed after the mechanical tests, and after conditioning in extreme environments. It was checked that the dielectric characteristics were maintained within the established limits.

Batches of used working equipment have been subject, depending on field of use, technical characteristics and manufacturer specifications, to visual inspection and dielectric tests.

Protective working equipment have been checked to identify visual defects (eg. missing parts, cracks, bumps, foreign inclusions, etc.) and to technical condition, mainly related to maintenance (traces of punctures, the flashover, dirt, moisture traces, mold, unauthorized modifications made by users, etc.). At 11% of the working equipment, cracks and blows were identified, and the working equipment did not pass the dielectric test.

Verification of the dielectric characteristics was performed in accordance with testing and working laboratory procedures, but taking into account the verification methods indicated by the manufacturers in the technical documents. During the tests, the leakage current, the flashovers and the local heating were monitored. It has been found that specimens that have lost the dielectric characteristic also show visible local heating (P Dašić et al., 2017). A comparison was made within values of leakage current degradation recorded during periodic safety tests and for some working equipment there was a greater decrease of dielectric characteristics for those stored in undeveloped environments. Figure 3 shows the results of dielectric characteristics tests for the insulating sticks batches in use.

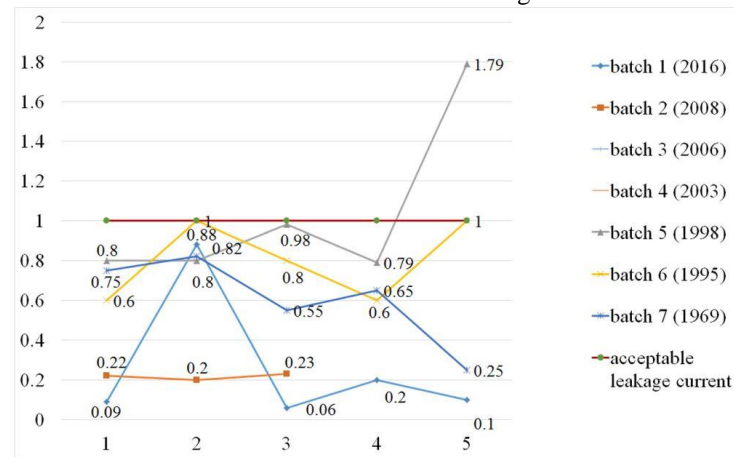


Fig. 3. Leakage current – insulating sticks in use

The results highlighted the quality of the materials of insulating sticks, respectively of the insulating hollow tubes and insulating materials and adhesive joint systems, as well as the way of using, maintaining, transporting and storing them.

There were other studies that investigate the comparative performances of new and used insulated sticks, with and without weather sheds fitted, under wet conditions. The tests investigated the time dependency of leakage current across the insulating surfaces when voltage stress was continuously applied for up to one hour, with the dry condition used as a reference baseline for comparison. This is seen as being representative of the practical situation in which a field operator must work (Williamson, Saha, 2002).

The results of the evaluation of insulating sticks in use are information on how to manage occupational hazards, the efficiency of selection and procurement procedures, the maintenance procedures and to establish the most appropriate technical diagnostic and inspection / control measures for a higher safety level of working equipment.

Awareness and involvement of top management is essential in the development of organizational risk management and to increase the risk awareness at different levels of the organization (G. Babut, R. Moraru, 2006).

#### 4. Conclusion

Insulating sticks must be designed and manufactured in such a way as to protect against electrical hazards in use in electrical installations.

The purpose of the study was to identify the technical and safety requirements for insulating sticks, in order to establish the necessary conditions for checking and testing new and used work equipment, in order to attest the technical and safety quality during their use.

The study also aimed at identifying the conformity assessment tools and technical diagnostics necessary to certify the conformity of insulating sticks, in order to develop power risk management methods, both for the most appropriate control measures in use and for selecting and acquiring them.

The technical and safety requirements applicable to insulating sticks are intended to provide the criteria underlying the management of the protective working equipment, required by both manufacturers and users, in order to adopt the best technical and safety solutions, to ensure their compatibility with electrical installations, and to ensure safe use and safe maintenance of this work equipment.

In addition, the management of risks generated by the working equipment and the means of protection in use allows for a safer and healthier work environment and to increase the competitiveness of companies on the market.

## References

- Antonov A., et al. *Management and control of occupational risk in the maintenance activities of work equipment in companies using software tools*, Environmental Engineering and Management Journal, Volume 13, No. 6, 1361-1354, (2014).
- Antonov A., et al. Risk assessment of work equipment in use - principle of compliance with the requirements of Directive 2009/104/EC, SESAM2017, (2017)
- Babut G, Moraru R, *General framework for environmental risk management*, Agir Bulletin 3, (2006)
- Buică G., *Contributions of diagnostic methods of safety and health at work in electrical installations*, Universitas, Petrosani, pp. 99 – 159, (2010)
- Charles Williamson, Tapan K Saha, *Wet-test Performance of Insulating Fibreglass Sticks Used for Live Working*, Journal of Electrical & Electronics Engineering, Vol 21, No.3, (2002)
- Darabont D, Antonov A, Bejinariu C, (2017) Key elements on implementing an occupational health and safety management system using ISO 45001 standard, International Conference on Manufacturing Science and Education – MSE 2017 “Trends in New Industrial Revolution”, Sibiu
- Dašić P. et. al., *High Accuracy Investigation of Microwave Absorption in Polymer Electrical Components on Motherboard of Computers*, International Conference on Innovative Research — ICIR EUROINVENT 2017
- Leba, M., Ionica, A., Dobra, R., Pasculescu, V. M., *Quality function deployment (QFD) based expert system for renewable energy structures. A wind turbine case study*. Environmental Engineering & Management Journal (EEMJ), 13(6), 1365-1370, (2014).
- Pasculescu V.M., Vlasin N.I., et. al., *Considerations on impact resistance tests for electrical equipment used in explosive atmospheres*, Proceedings of the 16th International Multidisciplinary Scientific Geoconference SGEM 2016, Section Science and Technologies in Geology, Exploration and Mining, Volume II, Albena, Bulgaria, 181-188, (2016)
- EO nr. 409/2016 - Laying down the conditions for making available on the market of low-voltage electrical equipment
- SR EN 50508:2009 Multi-purpose insulating sticks for electrical operations on high voltage installations
- SR EN 60832-1:2010 Live working - Insulating sticks and attachable devices - Part 1: Insulating sticks
- SR EN 60832-2:2010 Live working. Insulating sticks and attachable devices. Attachable device
- SR EN 62193:2004 Live working - Telescopic sticks and telescopic measuring sticks
- SR EN 60855:2003 Insulating foam-filled tubes and solid sticks for live working
- SR EN 60855-1:2017 Live working - Insulating foam-filled tubes and solid sticks - Part 1: Tubes and sticks of a circular cross-section
- SR EN 61235:1999 Live working. Insulating hollow tubes for electrical purposes



## Employees protection in maintenance activities. A statistic image

Radu Mareș<sup>a\*</sup>, Mihai Popescu - Stelea<sup>a</sup>, Roland Iosif Moraru<sup>a</sup>, Gabriel Bujor Băbuț<sup>a</sup>, Mariana Nagy<sup>b</sup>

<sup>a</sup>University of Petroșani, 20 Universității str., Petroșani 332006, Romania

<sup>b</sup> „Aurel Vlaicu” University of Arad

---

### Abstract

Maintenance activities are essential for maintaining the safety and reliability of the equipment and the working environment, it has a decisive impact on occupational safety and health, being a high risk activity that needs to be done safely, with adequate protection for maintenance workers and of other people present at the workplace. These activities include operations from very different sectors and from all types of work environments. This study highlights the impact of maintenance – as a high risk activity – on the safety conditions of the maintenance workers’ protection, within the post-accident evaluation and analysis of several organizations from Arad county.

*Keywords:* maintenance, risk, prevention, work accident, health and safety at work, statistic.

---

### 1. Introduction

In accordance with the European Standard 13306, maintenance is referring to "the combination of all technical, administrative and managerial actions over the lifecycle of a piece of equipment - a building, a work equipment or means of transport - in order to maintain or restore it in a state in which it can perform the desired function". Maintenance activities - Preventive and Corrective Maintenance - includes operations from extremely diverse sectors and across all types of work environments: inspection, testing, measurement, replacement, adjustment, repair, maintenance, troubleshooting, component replacement, service, lubrication, cleaning.

Maintenance is essential in maintaining the safety and reliability of the equipment and the working environment, it has a determining impact on occupational safety and health, being a high risk activity that needs to be done safely, with the proper protection of maintenance workers and of other people present at the workplace.

The lack of maintenance or inappropriate maintenance can lead to dangerous situations, accidents and health problems.

### 2. Workers’ protection in maintenance activities

In order to characterize and assess the time course of workers’ protection in maintenance activities (maintenance, repairs, cleaning, inspection - code 16-52, code 16-53 and code 16-55 from FIAM), the absolute statistical indicator was used "The number of accidents produced during 01.01.2011 - 30.09.2016", in organizations from Arad County.

Postaccident analysis and assessment allowed to highlights the dangerous actions and conditions that led to injury, in terms of injury occurrence and severity, of all data that may lead to the establishment of measures to prevent the risk of injury during maintenance activities.

During the analyzed period, during maintenance activities in Arad county, 33 work accidents were recorded, 30 accidents with temporary work incapacity, 3 fatal accidents, (fig.1).

---

\* Corresponding author. Tel.: +40 720499759  
E-mail address: radumares50@gmail.com



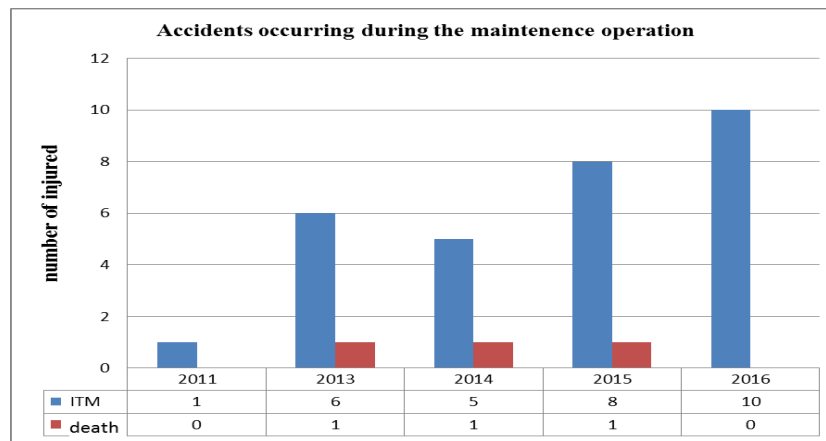


Fig. 1 Work accidents during maintenance activities

Compared to the total number of work accidents registered in the county, 458 cases, the work accidents in maintenance activities represent 7.2%.

The distribution of work accidents analyzed in relation with CAEN codification, regarding the economic activity that took place in the economic activities: manufacturing industry (section C, division 14; 16; 17; 22; 24; 25; 27; 28; 29 ; 30; 31), 32 cases; wholesale trade (section G, code number 45) one case - (figure 2).

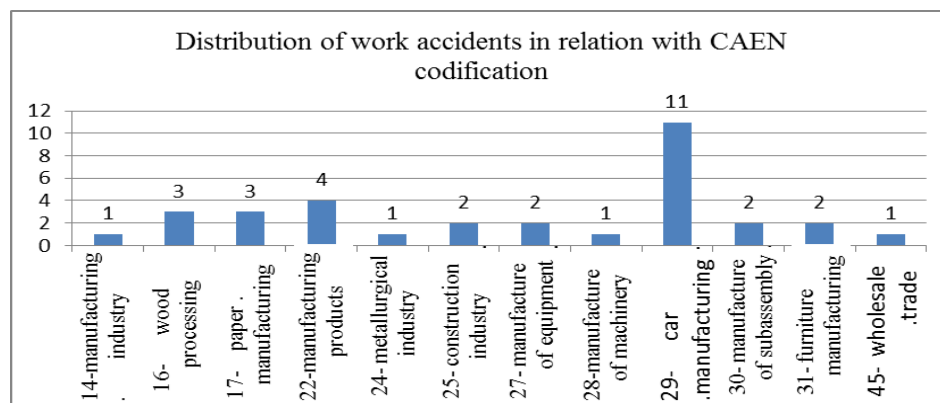


Fig 2 – Number of accidents / div. code C.A.E.N. "accident activity"

In the analysis carried out, we can notice that maintenance activity is found in 12 sectors of activity, compared to the 88 sectors of activity (divisions) that include the CAEN codification.

Regarding the working environment or all the factors where the victim was working at the time of the accident, the distribution of work accidents shows that most accidents occurred in production areas, factories, workshops - 30 cases; in maintenance areas, 1 case; storage 1 case; forest areas 1 case - (figure 3).

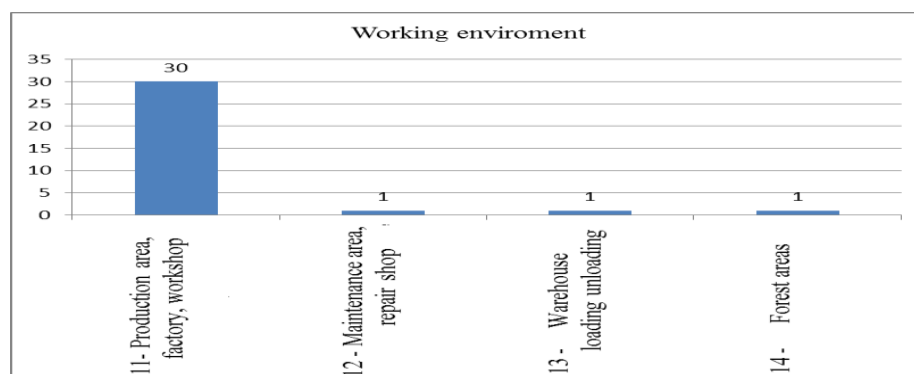


Fig 3 – Number of accidents / code „working environment"

### 3. Analysis of identification data and injured information.

Regarding the professional status, 98.1% of the injured persons were permanently working and full-time workers. The injured persons were 100% male; regarding marital status, 27 injured (81.81%) were married, 2 injured (6%) were unmarried, and 3 injured (9.09%) were divorced.

The criterion on the age of the injured person (Figure 5) shows that most of the injured belong to the age group 25-35 15 persons, the age group 45-55 9 persons, the age group 18-25 4 persons, age group 35-45 3 persons, and for the age group 55-65 2 persons.

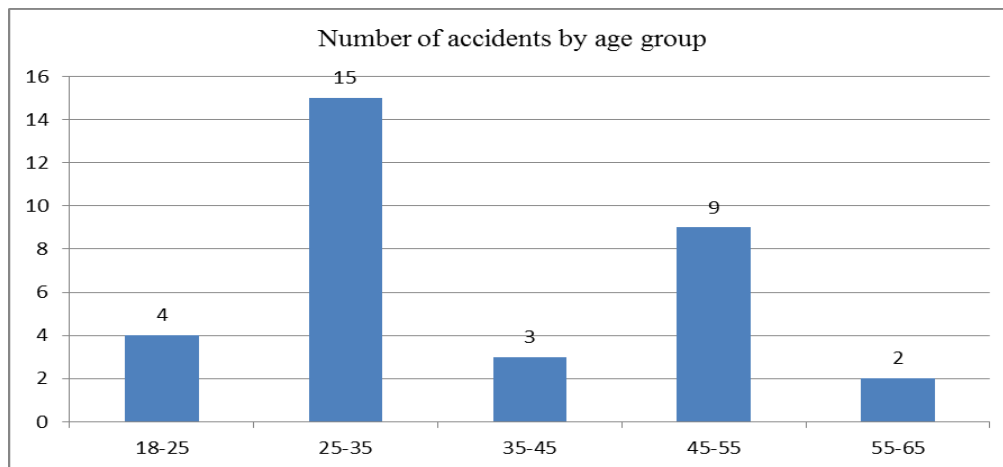


Fig 5 – Number of accidents / code, "injured age group"

#### 4. Data analysis of the time when the accident occurred.

Regarding the distribution of work accidents over the months of the year (Figure 6), there is generally a relatively uniform distribution with an increase in June, July and August 4, 5, 4 accidents, the factor being the "occasional or mobile point".

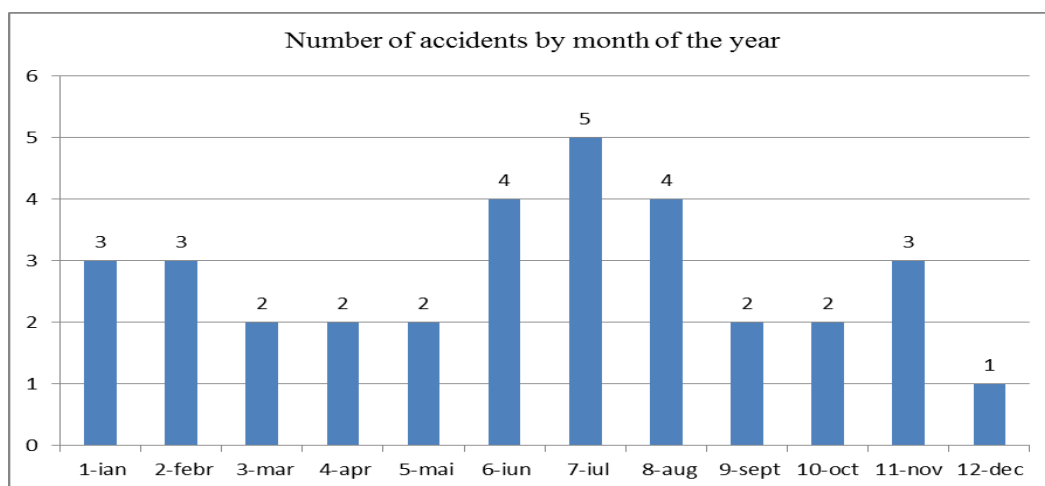


Fig 6 – Number of accidents / code "month of the year"

The "day of the week" criterion (Figure 7) shows a steady increase from the first day of the week on Monday, Tuesday (5 respectively 6 cases), with the peak on Wednesday 8 cases, followed by a steady decrease towards the end, so Thursday, Friday, Saturday and Sunday with 6, 4, 3 and 1 accident.

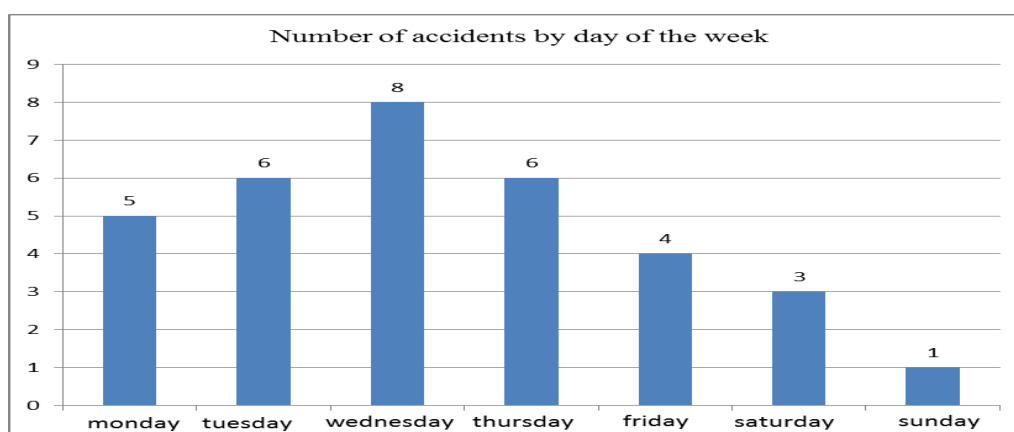


Fig 7 – Number of accidents / code "day of the week"

The "time of day" criterion (Figure 8) shows the distribution of work-related accidents over the hours, so it is noted that after an hour of work on shift 1, the number of accidents is 2 at 9 o'clock, double in the next hour to 4 accidents, followed by a decrease at 10, 11 and 12 (3, 2, 3 accidents). A significant increase of 5 accidents at 13 o'clock followed by a decrease and maintenance at 14, 15 with 4 accidents. In the second shift, the accident distribution is in the form of a curve beginning at 20 o'clock (1 accident), followed by a significant increase at 21 (3 accidents) and a decrease at 22 with 1 accident.

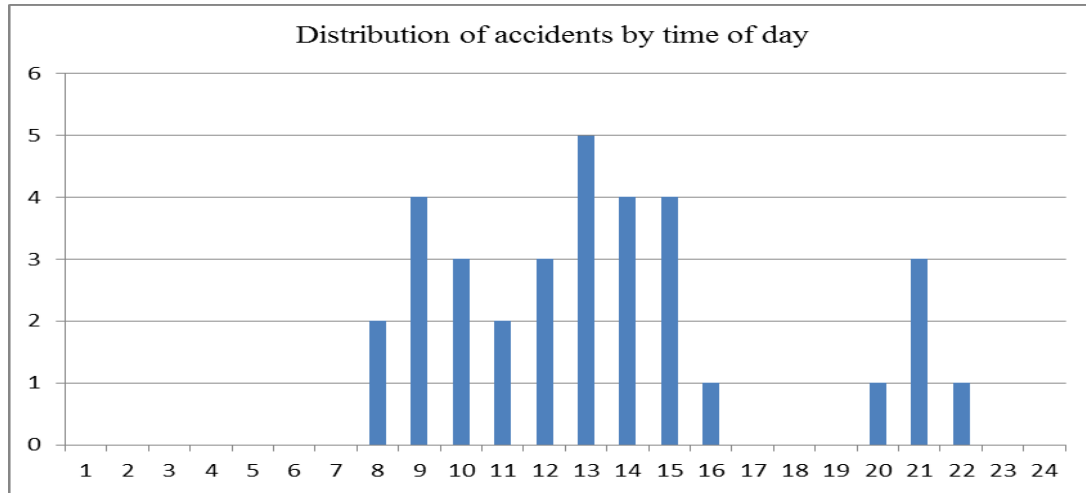


Fig 8 - Number of accidents / code "time of day"

## 5. Cause analysis in the labor accidents' dynamics.

In order to determine the most efficient measures to prevent the risk of injury in the maintenance activity (maintenance, repair, cleaning), we only approached the analysis of the causes depending on the "*executor* - the man involved in the work activity" and the "work task – the number of actions established and transmitted to the executor by the manager of the workplace", causes that are highlighted in "lit. (k) the cause of the event" in the event's investigation report and which are the main causes (*according to their importance in the work accidents' dynamics*), whose removal in the phase of risk factors, their occurrence could have avoided.

The analysis of the causes depending on the "executor" (Figure 4.11) highlights the inadequate behavior of the worker, reflected by his work capacity deficiencies, deficiencies that led to wrong actions or omissions, to an event-accident following:

- inadequate orders, code maneuvers 23.03 - 10 cases;
- not performing operations essential to work safety on time - code 23.02 - 8 cases;
- non-use of protective equipment, code 23.01 - 6 cases;
- exposure, outside work tasks, by displacement code 23.12 - 4 cases;
- falls from the same level by slipping, code 23.16 - 4 cases;
- falls from a high place, due to unbalance, code 23.20 - 2 cases;
- falls from a high place by slipping, code 23.21 - 1 case.

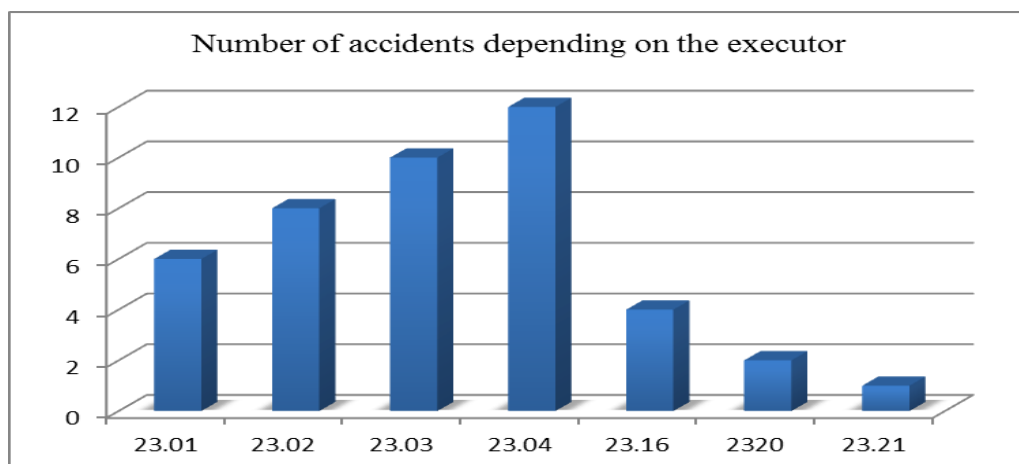


Fig 9 – Number of accidents / code, "depending on the executor"

The cause analysis depending on the "work task " (figure 10) highlights the inappropriate content of the work tasks under the report:

- omissions in pre-work tasks, code 23.092 - 8 cases;
- errors in pre-work tasks, code 23.093 - 8 cases;
- tolerance of technological discipline deviations, code 23.098 - 1 case;
- not securing the coordination of some work tasks performed in complex tasks
- accepting inappropriate production means, code 23.101 - 1 case;
- other causes, code 23.107 - 11 causes.

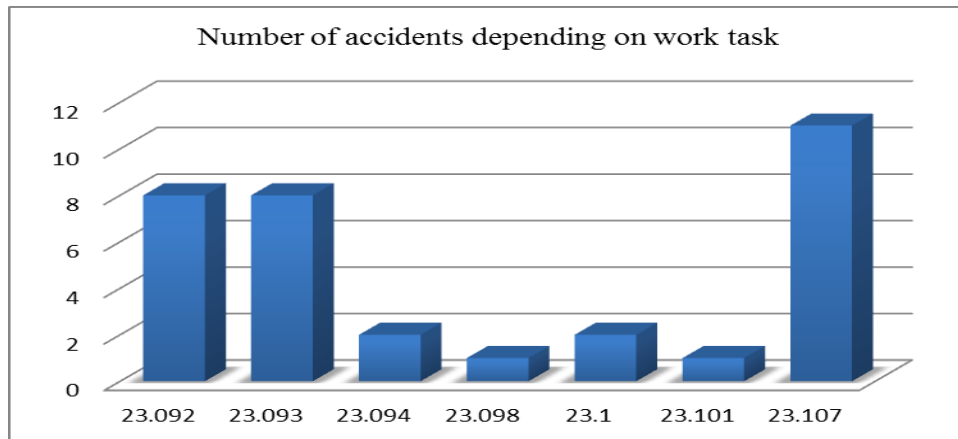


Fig 10 – Number of accidents / code, "work task causes"

## 6. Conclusions

The post-accident analysis and evaluation shows that the work injuries suffered by maintenance workers took place in very different activity sectors, in 13.63% of the activity sectors, compared to the 88 activity sectors (divisions) of the CAEN code.

Regarding the working environment, a multitude of types of working environments resulted (from code 011 to code 034, from position 15 FIAM, figure 4.6) where the group 011 predominates - productive area with 30 cases, factory, workshop, followed at a great distance by group 012 - maintenance area 1 case, repair workshops, group 013 - warehouses, loading / unloading 1 case and group 034 - forest areas 1 case.

Regarding the type of maintenance, the analysis showed that the "corrective/reactive" maintenance predominated, which restored the operating status of the damaged system, in 23 cases (69.6%), while the "preventive" maintenance with planned, proactive actions, through which the control of the deterioration process leading to system failure was found in only 10 cases (31.1%).

Maintenance is an activity that includes work near an ongoing process and in direct contact with the work equipment, this aspect being highlighted by the variable "deviation" as the last abnormal event leading to an accident, namely:

- deviation from checking the injured person, mainly caused by problems with the work equipment, eg: groups 10-30, with 3 cases;
- the loss (total or partial) of control over something, eg groups 40-50, with 14 cases;
- movements of the body, eg groups 60-70, with 10 cases, etc.

Regarding: professional status, the majority of 98.1% of the injured persons were permanent and full-time workers.

The injured persons were 100% male; with regard to civil status it is highlighted that 27 injured (81.81%) were married. The criterion "injured's occupation" reveals that most of the injured belong to the major group 7 - skilled craftsmen and workers (major subgroup 72 - working in metal constructions 12 cases, 75 - food industry 1 case); major group 8 - machine operators (major subgroup 81 - fixed installations operators, 4 cases, 82 - metalworking machinery operators 6 cases); Major group 9 - Unskilled workers (subgroup 92 - unskilled labor workers 1 case, subgroup 93 - unskilled construction workers 5 cases); major group of 3 technicians, foremen (subgroup 31 - technicians 1 case, subgroup 33 informatics and communications technicians 1 case); the major group 1 Subgroup 13 - 1 case; as well as 00 - unspecified 1 case.

The criteria for " the age of the injured person" shows that most of the injured belong to the age group 25-35 15 persons, the age group 45-55 9 persons, the age group 18-24 4 persons, the age group 35-45 years 3 persons and for the age group 55-65 years 2 persons.

The "injury location" criterion reveals that the most affected area was: *the upper extremities area* - 20 cases; *head area* 7 cases; *lower extremities area* - 6 cases.

The "month of the year" criterion generally shows a relatively uniform distribution with an increase in June, July and August of 4, 5, 4 occupational accidents, the factor being the "occasional or mobile point".

The "Day of the Week" criterion shows a steady increase from the first day of the week on Monday, Tuesday (5th respectively 6th), with the peak on Wednesday, 8th, followed by a steady decrease towards the end of the week, Saturday and Sunday with 6.4.3 and 1 accident.

The "Time of the day" criterion shows the distribution of work accidents over the hours, with an increase at around 9 and 13, when the most accidents occur (11 cases).

Regarding the causes of the injury, the prevention measures must focus on the components "executor" and the "work task".

Regarding the "executor" component, the need to promote a culture of prevention, acquiring knowledge and health and safety trainings at work must be an absolute priority in the occupational health and safety management system in the enterprise.

As far as the "work task" component is concerned, the activity of the managers must be informing and verifying the way work instructions in the maintenance activity are applied and also upon occupational safety and health norms.

## References

- Băbuț, G.B., Moraru, R.I., Băbuț, C.M., *Integrated Risk Assessment Methods (I)*, Quality - Access to Success, Volume 10, Issue 12, pp. 53-57, 2009.
- Băbuț, G.B., Moraru, R.I., Cioca, L.I., „Kinney methods”: *useful or harmful tools in risk assessment and management process?*, Proceedings of the 5th International Conference on Manufacturing Science and Educations (MSE 2011), Volume II, pp. 315-318, Sibiu, Romania, 02-05.06. (2011).
- Cioca, LI, Moraru, R.I., *The importance of occupational health and safety in the framework of corporate social responsibility*, Management of Sustainable Development, volume 2, nr. 2/2010, (revistă categoria B+) (Editor-in-chief: Constantin Oprean), University “Lucian Blaga” of Sibiu.
- Dura, C., Păun, A.P. Moraru, R.I., *Empirical Analysis on the Relationship between Corporate Health and Safety Performance and the Financial Outcome within Socially Responsible Companies*, Quality - Access to Success, Volume: 19, Issue: 162, Pages: 155-160, (2018).
- Moraru, R.I., Băbuț, G.B., Cioca, L.I., *Study of methane flow in caved goafs adjacent to longwall faces in Valea Jiului coal basin*, Proceedings of the 13th International Multidisciplinary Scientific Geoconference - SGEM 2013, Volume I, pp. 731-738, Albena, Bulgaria, 16-22.06. (2013).
- Moraru, R.I., Băbuț, G.B., *Principles and guidelines regarding the risk management implementation (I). The new ISO 31000: 2009 Standard*, Quality - Access to Success, Volume 11, Issue 4, pp. 50-59, 2010.
- Moraru, R.I., Băbuț, G.B., *On the culture - learning - participation triad in occupational health and safety management*, Quality - Access to Success, Volume 13, Issue 131, pp. 99-107, 2012.
- Moraru, R.I., Băbuț, G.B., *Ethics and Stakeholder Involvement in Occupational Risk Management (II)*, Quality - Access to Success, Volume 12, Issue 4, pp. 72-79, 2011.
- Moraru, R.I., Băbuț, G.B., *Principles and guidelines regarding the risk management implementation (II). The new ISO 31000: 2009 Standard*, Quality - Access to Success, Volume 11, Issue 5, pp. 56-63, 2010.
- Moraru, R.I., Băbuț, G.B., Popescu-Stelea, M., *Approaching occupational safety and health emerging risks categories and prevention*, Quality - Access to Success, Volume 15, Issue 139, pp. 104-108, 2014.
- Moraru, R.I., Băbuț, G.B., Popescu-Stelea, M., *Prerequisites for safety diagnostic and risk analysis integration in complex industrial facilities*, Quality - Access to Success, Volume 17, Issue 151, pp. 92-99, (2016).

## Management of dangerous substances released by machinery, condition to ensure safety and workers' health and environmental

Anca Elena Antonov\*, Georgeta Buica<sup>a</sup>, Constantin Beiu<sup>a</sup>, Raluca Aurora Stepa<sup>a</sup>

*INCDPM “Alexandru Darabont”, 35A Blvd Ghencea, 6<sup>th</sup> county, Bucharest 062692, Romania*

---

### Abstract

The research is aimed at identifying the applicable safety requirements for the prevention of occupational risks in the management of dangerous substances related to the use of machinery. For the use of machinery in conditions of economic performance and a maximum level of safety, it is necessary to ensure that the conditions set by the manufacturer regarding the putting into service, use and interventions under the conditions of safety work and guarantee of technical and environmental requirements, including measures and means of protection against the action of dangerous substances used or produced by machines. The prevention of this specific risks can be achieved by avoiding the use of dangerous materials and substances or by using less dangerous substances. The specific occupational hazards impact of machines can be reduced by applying modern principles in conformity assessment, taking into account the provisions of the Machinery Directive which imposes an obligation on manufacturers to ensure compliance with safety and health requirements both technical point and on safety work environment. The research paper aims to develop a risks management methodology based on the dangerous substances produced and/or used by the machinery to ensure compliance and to provide the premise for increasing employers' competitiveness.

*Keywords:* risk, safety, machinery, dangerous substaces, management

---

### 1. Introduction

The modern economy is the result of industrialization and economic and social progress, requiring modern, high-performance, high-performance working equipment and installation facilities to ensure high economic efficiency. To use working equipment in conditions of economic performance and a maximum level of safety, it is necessary to ensure that the conditions set by the manufacturer regarding the putting into service, use and maintenance in proper conditions are met and to guarantee the technical and environmental requirements, including measures and means of protection against accidents and occupational disease. An important national objective is to ensure the essential safety and health requirements applicable to all working equipment, in order to implement the policies provided by the free movement of goods contained in the EUROPA 2020 strategy, namely to guarantee the free movement of Romanian products within the European Union (EU) (Antonov et al., 2017).

Another objective is to ensure the safe use of working equipment (WE) from which the machinery belongs, in order to prevent the risks of accident and occupational disease, as well as to protect the working environment and the environment, by putting into service of compliant products, including measures and means of protection against the action of hazardous substances used or produced by machinery. The prevention of risks from emissions of hazardous substances can be achieved by avoiding the use of hazardous materials and substances or by using less dangerous substances. Working equipment must be designed and built in such a way to be able to perform its function and be used, adjusted and maintained without the working being exposed to risk when such operations are carried out under the conditions laid down by the manufacturer, and taking into account any foreseeable misuse that can be predictably expected. Working equipment must be delivered with all essential components and accessories so that it can be adjusted, maintained and used in complete safety.

In order to prevent risks from emissions of hazardous substances, the machinery manufacturer and employers, as a user of the working equipment, must identify the hazards and carry out the assessment of the foreseeable risks resulting from the dangerous substances produced and/or used by the machinery, in order to guarantee the health of workers at work. This process must cover, as far as possible, any potential hazard that may arise from the exposure of individuals at any stage of machinery life cycle. The research study focuses mainly on the analysis undertaken to identify the measures to be taken to increase the compliance rate of WE in use and to prevent risks from emissions of hazardous substances.

The methods used are:

- identification of professional risks applicable to the machinery, which is the subject of the study analysis;
- establishing the essential safety and health requirements applicable to machinery, in accordance with the legal provisions set out in Annex no.1 of EO no.1029/2008, which adopts the Machinery Directive 2006/42/EC (Machinery Directive);
- establishing the safety and health requirements applicable to machinery, in accordance with the legal provisions set out in Annex no.1 of EO no.1146/2006, which adopts Directive 2009/104/ EC (Work equipment Directive);
- establishing the safety and health requirements applicable to the machinery in relation to the risks generated by the emissions of dangerous substances, according to the legal provisions set out the specific safety standards analyzed in the study.

## 2. Work accident statistics in agriculture and processing industries

Statistical data on work-related accidents at national level in Romania are based on the data provided by the National Statistics Institute (NSI) for the period 2013-2016 (NSI TEMPO, 2018). It was taken into account in the analysis of the statistical data related to the work accidents and the information provided in the Romanian Labor Inspection through the Activity Reports for 2013-2017. Also, from the statistical data provided by EUROSTAT and from the analyzes based on the SEAM methodology (European Workplace Accidents), it can be identified work accidents as a result of maintenance operations in several European countries (EU OSHA, 2010; EUa, 2001). Accidents at work have an increasing tendency not to occur during normal operation, but during repair, maintenance, cleaning, adjustment, etc. (Dobra R et al., 2013; EUB, 2010).

An analysis of the results of the Spanish National Survey on Working Conditions (2007) indicates a greater exposure of maintenance workers to noise and vibrations affecting hands, arms and the whole body as compared to other workers. They are also more exposed to dangerous substances, vapors and emanations (Garcia Morilla et al., 2003).

Approximately 25% of all electrical accidents with injuries are caused by portable electrical equipment. Damaged conductors from working equipment annually cause around 2000 fires. A major cause of these accidents and fires is the failure to carry out inspections and maintenance. (EU-OSHA and b) The research shows the results of the processing of statistical data regarding the work accidents produced at national level, by macro-regions, development regions and counties, respectively economic activities as a number of collective accidents, according to Fig. 1.

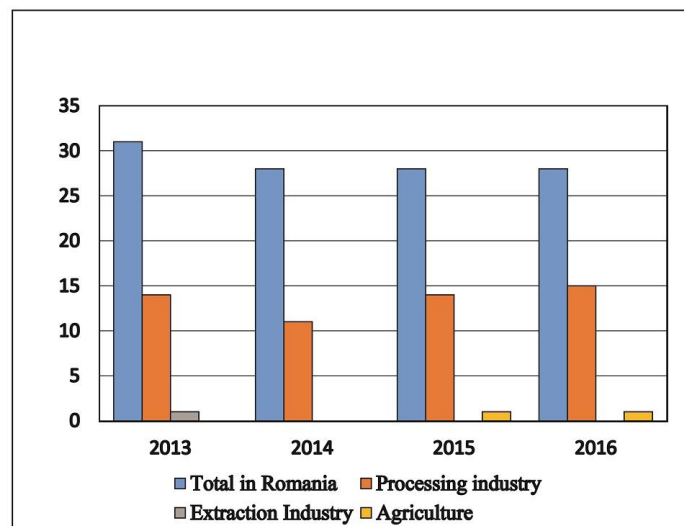


Fig.1. Collective accidents at work at national level during 2013-2016

Fig. 2 shows the situation of work accidents on categories of accidents, macro-regions, development regions and counties specific to agriculture, the mining and processing industries, in the period 2013-2016, according to the NSI registration. (NSI TEMPO, 2018).



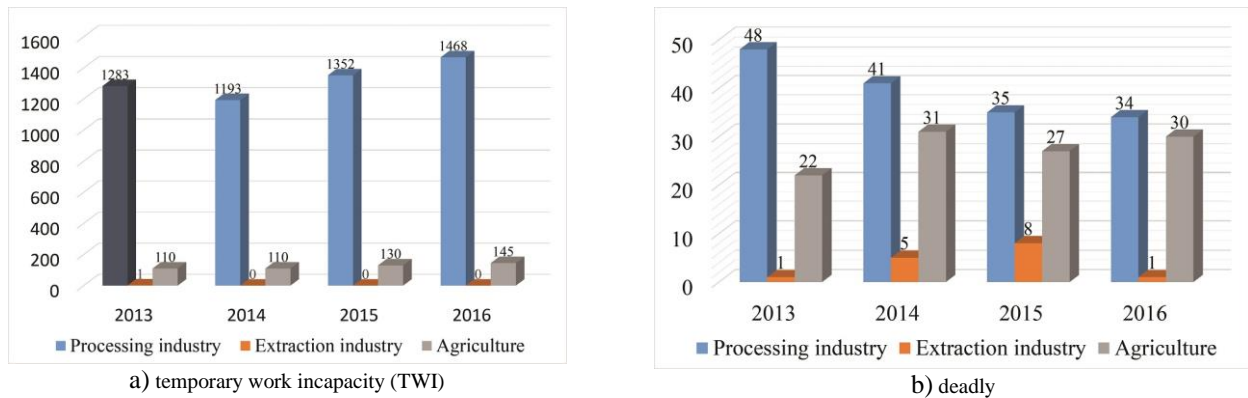


Fig.2. Accidents at national level during 2013-2016.

In the research study, the results of the processing of statistical data on work-related accidents at national level are presented (NSI TEMPO, 2018). According to the data available at the national level (NSI), processed by the authors of the research study, the above graphs, shows the distribution of the accidents at work produced in Romania, the statistics and the data collected from the activity reports of Labor Inspectorate during 2013 -2017 does not highlight the direct causes of occurrence of these accidents, the results of the accident investigation produced in these sectors of activity being recorded and declared in the files drawn up at the employers level, at Territorial Labor Inspectorates and, as the case may be, at the National Labor Inspectorate. Analyzing the statistical data, it was found that the agriculture, extractive industries and processing industries remain in the first places in terms of number of injured in work-related events. Statistical data on national accidents at work shows that there is an increase in the number of accidents at work during 2013-2016 in agriculture and extractive industries, with a decrease in the processing industries in the case of TWI, respectively an increase in the number of dead workers in the agriculture and processing industries. In order to ensure safe machinery in use, the designer and the manufacturer must ensure the compliance with national and European legislation, applicable national and European standards and national and Occupational Safety and Health (OSH) documents developed by employers (Antonov et al, 2017).

### 3. Identifying the applicable safety requirements to prevent risks from hazardous substances

From the studies carried out on the evaluation of the risk level and the working conditions during maintenance operations in the 4 categories of working equipment, it was found that the most significant are the mechanical and electrical risks, which may influence the characteristic factors of the emission of hazardous materials and/or substances (Dobra R et al, 2013). Identifying, analyzing and assessing the risks of injury and occupational disease generated by working equipment are the basic tools of risk management, in order to reduce and to eliminate these risks by technical and organizational measures. The benefit of risk assessment allows to identify the problems faced by users, which requires the adoption of preventive measures (Antonov et al, 2016).

The main source of a technical event with consequences, both at the employer's and worker level, is the working equipment. Risks related to the impact of workers' health are generated by a multitude of machinery-specific risk factors and workplace organization. A category of risks that affect the workers' health and can generate a work event is due to the emissions of hazardous materials and substances produced by the machinery. Dangerous materials and substances include both chemical and biological materials and substances classified as toxic, corrosive, irritant, carcinogenic, mutagenic, teratogenic, pathogenic or asphyxiating (EC b, 2010). The level of risk depends on the properties of the hazardous substances, the likelihood of being personal, the exposure to occur and the degree of exposure. The effects on workers' health caused by emissions of hazardous substances by machinery may be on short or long term and depend on reversible or irreversible nature. Dangerous substances may appear in any physical state (gaseous, liquid, solid) and may affect the human body by inhalation, ingestion, contact with the skin, eyes and mucous membranes or penetration through the skin, which can be generated from any part of the machinery substances present in the machinery or materials that result directly or indirectly from materials and/or chemical or biological agents processed or used by the machinery or, as the case may be, used on the machinery. Airborne emissions of dangerous substances may enter in the body by inhalation or other ways when deposited on the surface of the body or ingested. Emissions of non-airborne hazardous substances may enter in the body by ingestion or in contact with the skin, eyes or mucous membranes. The prevention of risks from emissions of hazardous materials and substances can be achieved by avoiding the use of hazardous materials or substances or by using less dangerous substances.

The machinery manufacturer must identify hazards and assess the foreseeable risks from hazardous substances. Risk assessment should extend, wherever possible, to all potential hazards of exposure of workers in all different life phases of the machinery. The machinery manufacturer must design the production process to avoid or reduce emissions. Where



emissions of hazardous materials and substances cannot be avoided or reduced sufficiently, the machinery must be equipped with necessary equipment to retain, evacuate or precipitate hazardous materials and substances in order to protect workers against exposure. Where dangerous materials or substances are flammable or may form explosive mixtures with air, the necessary precautions shall be taken to avoid the risk of fire or explosion during their retain or evacuation. The safety and health requirements applicable to machinery for airborne emissions, in order to prevent risks from hazardous materials and substances, are provided in the applicable safety standards of SR EN ISO 14123-1: 2016 and aim at the necessary measures to be taken by the designer and the manufacturer of the machinery, in order to eliminate and to reduce the emissions that can come from different sources as much as possible, namely: processing, grinding, sanding, milling; evaporation or thermal convection; hot metal processing; material handling; spraying; leaks; waste; maintenance; dismantling; combustion of fuels; machinery for mixing food or metal processing. In the same way, the safety and health requirements applicable to machinery for non-airborne emissions aim at the necessary measures to be taken by the designer and manufacturer, in order to eliminate and to reduce as much as possible the emissions that may occur under certain circumstances, namely: migrants coming from open sources, which lead to secondary emissions; machinery openings; doors for inspection; manipulation of materials; manipulation of machine parts; incorrect operations; leaks or breaks.

Table no.1 presents the machinery risks related to the emissions of hazardous materials and substances in compliance with the applicable essential requirements provided by, Annex 1, chapter 1 and, as the case may be, 4, 5 of EO no.1029 / 2008 and under reference of harmonized standard SR EN ISO 14123-1: 2016

Table 1. The technical and safety requirements applicable to machines that produce and / or use hazardous materials and substances

Nr. crt.	Technical and safety requirements	Legal provision		Technical and verification conditions	
		EO no.1029/2008	EO no. 1146/2006	SR EN 14123-1:2016	SR EN 14123-2:2016
1.	Emissions of hazardous airborne substances	1.5.13	2.5	5.1	3
		1.1.3	2.6	4	4
		3.5.1	2.13	6	5
		3.5.3	2.15	8	
2.	Emissions of hazardous substances which are not airborne	5.5	2.17, 2.18	5.2	
			3.3.1.1	4, 6, 8	
3.	Fire	1.5.6	2.18	-	-
		3.5.2	3.16		
		5.6	3.3.1., 3.3.5		
4.	Explosion	1.5.7	2.18	-	-
			3.3.1, 3.3.5		

Where it is foreseeable that leakages, accidental spills or uncontrolled losses of hazardous substances may occur, the manufacturer must indicate the measures to be taken to limit the consequences and, respectively, to regain control of the situation as soon as possible. This information should refer, as appropriate, to emergency procedures, safe disposal of the substances and to protective equipment and devices in such way to allow the complete identification of the places where loss of substances occur and to make the necessary repairs. The manufacturer must provide adequate information on the necessary personal protective equipment and hygiene measures.

#### 4. Management of hazardous substances emitted by machines, a condition for ensuring the safety and health of workers

The impact of machine-specific occupational hazards due to emissions of hazardous chemical mixtures and/or substances not may or not be reduced by applying modern principles in conformity assessment, certification or technical diagnosis and inspection, taking into account the provisions of Machinery Directive 2006/42/EC that sets the obligation for manufacturers to ensure compliance with the applicable safety and health requirements, both technically and in terms of workplace and environmental protection, provided that the production process is designed to avoid or reduce emissions. The management of hazardous substances emissions from machines is a condition to ensure the safety and health of workers and environmental protection. Equipment play an important role in injuries of workers or private individuals.

Specific data for Romania could not be found, but data is available for the USA. A study published in 2015 by the Centers for Disease Control and Prevention in the reporting period (1999-2008) reveals the number and percentage of contributing factors associated with the top five chemicals released - Hazardous Substances Emergency Event Surveillance System, nine states. (CDC, 2015)

Table 2. Number and percentage of contributing factors associated with top five chemicals released — Hazardous Substances Emergency Events Surveillance system, nine states, period 1999–2008

Factor	Carbon monoxide		Ammonia		Chlorine		Hydrochloric acid		Sulfuric acid	
	No.	(%)	No..	(%)	No.	(%)	No..	(%)	No.	(%)
Equipment failure	200	(45)	242	(46)	86	(32)	47	(22)	89	(41)
Human error, unspecified	185	(42)	133	(25)	99	(37)	87	(41)	74	(34)
Others	59	(13)	154	(29)	85	(31)	77	(37)	52	(25)
Total	444	(100)	529	(100)	270	(100)	211	(100)	215	(100)

The general public represented 48% of the injuries for carbon monoxide, 23% for ammonia, 48% for chlorine, 31,9 for hydrochloric acid and 15 % for the sulfuric acid, while the unknown injured represented between 0,1 % and 0,5 %. The rest were employed persons, (CDC, 2015)

In order to manage the specific risks due to emissions of hazardous substances, the machine manufacturer or the employer who uses this equipment at the workplace must carry out a specific risk analysis, also taking into account the risks that are additional to the major/main risk. Reducing the risk of fire involves taking several combined measures.

The research study identified the necessary conditions for developing a risk management methodology based on the hazardous substances produced and/or used by the machines, in order to ensure compliance and to provide the premises for increasing company's market competitiveness. The developed methodology leads to the application of the procedures for checking the reduction of the health risks due to the hazardous substances from the machinery, which must comply with the principles and technical requirements stipulated in the harmonized standard SR EN ISO 14123-2: 2016. The test methods are chosen according to the air sampling and analysis methods for the pollutants adapted to the nature of the pollutants emitted. The choice of test methods to measure the emission of airborne hazardous substances must comply with the principles and technical requirements laid down in harmonized standards SR EN 1093-1:2009 and SR EN 1093-(2 ÷ 11) + A1:2008 series.

For the assessment of workers exposure to substances that become airborne after being emitted while operating/testing/doing maintenance for the machinery, techniques for measuring the concentrations of these substances in the breathing zone of workers in the machine area shall be applied. The results of the measurements shall be compared with the occupational exposure limit values (OELVs) established by the national regulations regarding the exposure of workers to chemical agents. Where national OELVs are not available, measurement results may be assessed against OELVs used by other countries or internationally recommended. Sampling methods and analysis techniques should be adapted to the nature of the pollutants emitted. Emissions of non-airborne substances cannot be measured by measuring their concentration in air, in which case other assessment criteria may be established based on the measurement techniques laid down in harmonized standard SR EN ISO 14123-2:2016 or by verification procedures developed by testing /analysis laboratories. Taking into account the steps leading to the implementation of the established verification procedures used in order to comply with the requirements of the harmonized standard SR EN ISO 14123-2:2016, the risk management methodology for hazardous substances produced and/or used by the machines developed in the research study considers the following: identification of hazardous chemicals; identification of the risks of emissions of hazardous chemicals produced or used in machine; characterization of significant emissions of identified hazardous chemicals; identifying the critical, relevant factors that can generate an emission and that should be addressed in order to avoid or lower emissions; establishing the characteristic parameters, which can be qualitative, in direct relation to the identified critical factors; collecting data on characteristic parameters by checking the results of on-the-spot tests / measurements, laboratory tests, measurements, examinations or calculations, as appropriate. Within the methodology developed by the research team, account is taken of both the types of emissions (that fall into the categories: zero or insignificant, localized or total, where emissions can be identified from several possible points) as well as the relevant factors and characteristic parameters such as: design, performance determined by the technical solutions adopted, materials, energy. The risk management methodology for hazardous substances produced and/or used by machines aims at making the conformity assessment and certification process more efficient and ensuring the necessary conditions for the safe use of work equipment and the management and control of occupational hazards at the users level, in order to improve the level of safety and health at work and the OSH management activities respectively.

Specific tools for conformity assessment, inspection, certification and compliance through technical diagnostics of work equipment, of which the machines are part, are required within the company management system, allowing for the technical framework necessary to control and guarantee the fulfillment of the specific security requirements related to hazardous substances, in conjunction with the specific requirements identified based on the risk analysis performed according to the harmonized standard SR EN ISO 12100: 2010. Risk management for specific processes e.g. metal and woodworking with their specific work equipment should start at the design and manufacturing level to ensure the necessary conditions for placing on the market of safe products with an adequate level of safety under the conditions intended use set out in the instructions in the Technical Manual/User Manual/Instructions.

## Conclusion

The research study aimed at developing the necessary tools to ensure compliance of machinery and other work equipment intended for placing on the market or in use at employers' level with the Machine Directive 2006/42/EC, in conjunction with Directive 2009/104/EC, the Law No.319/1996 on Occupational Safety and Health and the Social Directives on the exposure of workers to chemical and biological agents. The research addresses the need to ensure compliance with the essential health and safety requirements set out in Annex no.1 to Directive 2006/42/EC, in conjunction with the minimum safety and health requirements of Directive 2009/104/EC and the technical rules laid down through the safety standards applicable to machine with regard to the risks related to the emissions of hazardous substances produced and / or used by the machine.

The research study aimed at identifying the applicable safety requirements for the prevention of hazards caused by hazardous substances in order to manage the hazardous substances related to the use and maintenance of the machine, in relation to the tuning, repair and cleaning operations, including situations arising after events, major repairs and upgrades.

The risk-management methodology for hazardous substances produced and / or used by the machines developed in the study will allow compliance and provide the premises for increasing the competitiveness of employers in the market economy in order to help the safe use of the machines and the effective control of professional risks at the user level. The tools developed in the research study aimed to create the framework necessary to improve the level of safety and health at work in the workplace and the level of OSH management activities, respectively.

## References

- Antonov A., et al. *Management and control of occupational risk in the maintenance activities of work equipment in companies using software tools*, Environmental Engineering and Management Journal, Volume 13, No. 6, 1361-1354, (2014).
- Antonov A., et al. *Risk assessment of work equipment in use - principle of compliance with the requirements of Directive 2009/104/EC*, SESAM2017, (2017)
- CDC On line at: [<https://www.cdc.gov/mmwr/preview/mmwrhtml/ss6402a6.htm>] ranked the five substances that have caused the higher number of incidents, nine states in the USA (Colorado, Iowa, Minnesota, New York, North Carolina, Oregon, Texas, Washington, and Wisconsin), (2015)
- Dobra R., Buica G, Pasculescu D, Leba M *Safety Management Diagnostic Method Regarding Work Cost Accidents from Electrical Power Installations*, In: *Recent Advances in Industrial and Manufacturing Technologies*, WSEAS International Conference, Athena, Greece, vol. 1, 58-63, On line at: <http://www.wseas.us/e-library/conferences/2013/Vouliagmeni/INMAT/INMAT-08.pdf> (2013)
- EO no.1146/2006 On line at: <http://www.mmuncii.ro/pub/imagemanager/images/file/Legislatie/HOTARARI-DE-GUVERN/hg1146-2006.pdf>
- EO no. 1029/2008 On line at: <http://www.mmuncii.ro/pub/imagemanager/images/file/Legislatie/HOTARARI-DE-GUVERN/HG1029-2008.pdf>
- EU-OSHA (a) *Maintenance and Occupational Safety and Health: A statistical picture*, (2010)
- European Commission (a), *European statistics on accidents at work (ESAW) – methodology*, Brussels, European, Commission Directorate-General for Employment and Social Affairs, (2001).
- García Morilla, E., Santurio Diaz, J.M., Ferrera Cuervo, A., López Arias, V.M., et al., *Proyecto de estudio de vibraciones en maquinaria de obras públicas* [part 1 of 2], Asturias Prevención, No. 3, pp. 39-43 [<http://iaprl.asturias.es/export/sites/default/pdf/publicaciones/revista/asturias03.pdf>], (2003).
- INS *Data collected through the TEMPO Program managed by INS*, On line at: <http://statistici.insse.ro/shop>, (2018)
- SR EN ISO 14123-1:2016 *Safety of machinery — Reduction of risks to health resulting from hazardous substances emitted by machinery — Part 1: Principles and specifications for machinery manufacturers*

## Analysis of the methods of exploitation applied to Romanian salt mines

Chiuzan Emeric<sup>a\*</sup>, Găman George<sup>a</sup>, Tomescu Cristian<sup>a</sup>, Matei Adrian<sup>a</sup>, Drăgoescu Răzvan<sup>a</sup>

National Institute for Research and Development in Mine Safety and Protection to Explosion, INSEMEX, 32-34 G-ral Vasile Milea street, Petroșani, 332047, Romania

### Abstract

Salt is a vital food that has begun to be consumed since the Neolithic period. The history of salt is tumultuous and involves, among other things, the liberation of a people from foreign occupation. Man began to consume salt since the Neolithic period, when he began to diversify his diet and eat vegetal products. Man learned to use salt and became dependent on it probably in the Neolithic, when the transition has been made from an exclusively carnivorous diet to a diet with vegetable products. In 2018, in Romania, three methods of extraction of dried salt are applied, namely: i) method of operation in small rooms and square bunk pillars; ii) method of operation with small rooms and square pillars; iii) small room method and rectangular bunk pillars.

**Keywords:** exploitation, method, salt;

### 1. Introduction

Nowadays, in Romania are 6 underground salt mines in operation, belonging to teh National Salt Society located in Bucharest. The 6 salt mines presented in Fig. 1 are: Cacica, Ocna Dej, Praid, Slanica Prahova, Ramnicu Valcea and Tg. Ocna. Besides these, salt is also mined with the humid method in Ocna Mures, Tg. Ocna, Cacica and Ocnele Mari (Tamas et al., 2015).



Fig. 1. Romanian salt mines in operation

Three hypotheses have been drawn up concerning the origins of salt:

- The first one admits that salt dissolved within marine waters and the one from the earth's bark originates from the primordial atmosphere of our planet.
- The second one states that salt was generated by substances released from volcanic eruptions.

\*Chiuzan Emeric, Tel.: +40-254-541-621; fax: +40-254-546-277.  
E-mail address: emeric.chiuzan@insemex.ro.

- The third admits that salt originates from substances from decomposing miners from the earth's bark.

Some authors state that marine salts started to deposit in a system of lagoons of various dimensions and low depths, in hot climate, slow subsidence of the lagoons bottoms and the presence of a system of large barriers. Small and intermittent lagoons which retained from marine waters calcium and magnesium carbonates, which deposited as dolomites, into the large Transylvanian lagoon (represented by Transylvania and Maramures basins), waters full of sodium chloride and potassium and magnesium salts deposited as salt by cooling down (Fig. 2).

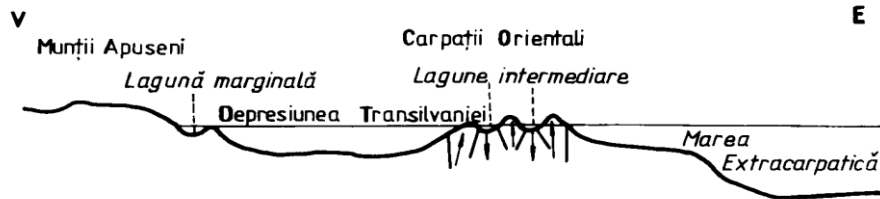


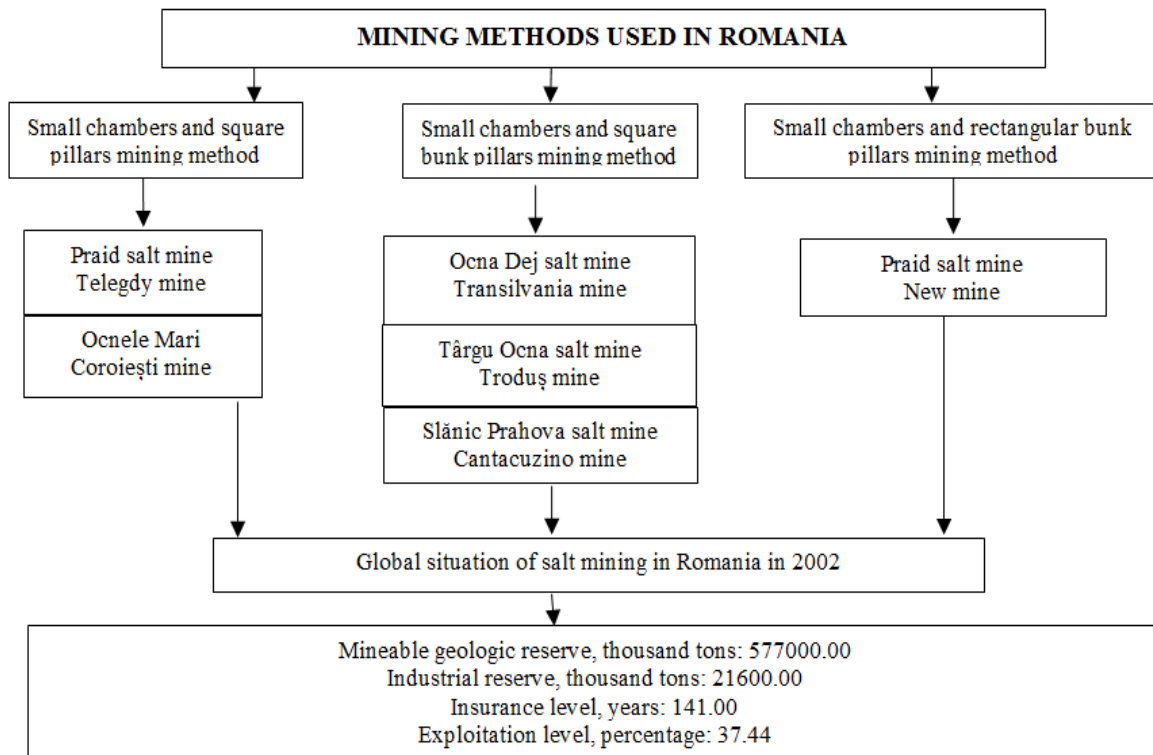
Fig. 2. Configuration of intermediate lagoons

## 2. Salt mining methods. Generalities.

In 2017, in Romania were applied only three salt mining methods, namely (Table 1):

- Small chambers and square bunk pillars mining method;
- Small chambers and square pillars mining method;
- Small chambers and rectangular bunk pillars mining method.

Table 1. Mining methods used in Romania



### 2.1. Small chambers and square pillars mining method

The method consists of excavating-blasting of chambers, between which are abandoned parallelepipedic pillars with square base. The exploitation direction is in advance (Fodor, 2015). The chamber-pillar system forms a well-established operational system, the chamber ensuring the space required for extracting the raw material and the pillar the stability of the salt massif. This method involves supporting the roofs of the exploitation chambers and the square pillars, but do not exclude this support when there occur instability phenomena (exfoliation, fissures of roofs and pillar etc.)

In the absence of these phenomena, the rock mass from the roof and pillars has to be maintained in balance, by a proper sizing of the mine's resistance elements, so that the salt between the pillars and roofs to unjustifiably increase operating losses.

Dimensions of the chamber-pillar are gap correlated for 30 m. The gap is the distance between the central vertical axis of two neighbouring chambers, separated by a pillar.

The exploitation method with small chambers and square pillars used in most salt mines has a series of advantages (Chiuzan, 2018; Oprina, 2015):

- The use of machinery is light, taking into account the gauge of the chamber;
- There may be opened a larger number of active work faces located at the same horizon;
- The ventilation network is diminished a lot, not being required special works for each chamber;
- There can be easily avoided waste or low-quality salt areas from the deposit (Leba et al., 2014).

Fig. 3 shows a horizontal section through an exploitation system, where (lp) stands for the width of the pillar, (lc) for the width of the chamber, (e) for the gap. The exploitation coefficient is depending on the gap: inversely proportional with the dimension of the pillars, directly proportional with the dimension of the chambers. Fig. 4 presents the chamber-bunk rectangular pillar system, where g-thickness of the roof, h-height of the chamber, l-width of the chamber, f-pillar.

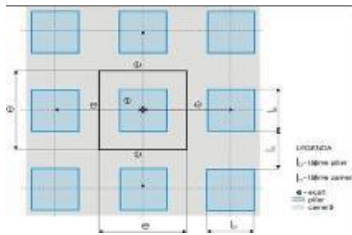


Fig. 3. Horizontal section

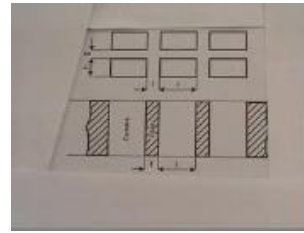


Fig. 4. Horizontal section through the chamber-rectangular pillar system

## 2.2. Small chambers and rectangular pillars mining method

This method differs from the one presented before only by the shape (rectangular in section) and dimension of the pillars and chambers. Horizontal and vertical gap is larger than for the previous method. This mining method consists in the excavation in the salt massif of chambers of 20 m width and 8-12 m height, separated by rectangular shaped salt pillars (Covaci et al., 1999). These pillars shall take the load of covering rocks, ensuring the stability of the excavation and of the surface. The mining method does not involve the support of chamber roofs and abandoned pillars, but does not exclude it when instability phenomena occur. The exploitation method is developed by MINESA - I.C.P.M. Cluj and it is exclusively used in Praid salt mine – new sector (lower horizons) and is characterised by the following (ICPM Cluj projects, 1986-2014; Popa et al., 1993):

- Roof (pillar) of the salt deposit has a minimum of 30 m thickness;
- Floor pillar of the salt deposit has a minimum of 25 m thickness;
- Marginal pillars for the new sector of Praid salt mine shall have a thickness of 30 m min.;
- Pillars (roofs) between horizons have a min. 8m thickness;
- Pillars between chambers are prisms with width of 20m, length of 40-100m and height of 8-12 m;
- Exploitation chambers with straight roof, width of 20m, height of 8-12 m and length of 20-300m.

Work procedure is the following:

- There is performed the main ventilation gallery (Cioclea et. al, 2015; Cioclea et al., 2014), of 6sqm, connected to the ventilation rising;
- Using the URAL-33 cutter (Fig. 5) is cut a channel in the floor, having 1.8m in depth.
- Workface is perforated using RADA-TELEMAC or SECOMA perforation installation (Fig. 6.);
- Perforated boreholes are loaded with explosive;
- Workface is blasted in two steps (240mp or 200mp);
- Workface is ventilated for 1 - 2 hours;
- Roof and walls of the chamber are lined of the freshly blasted slice using the HAULOTTE nacelle (Fig. 7) and the previous slices are verified;



Fig. 5. URAL-33 cutter



Fig. 6. SECOMA perforation installation





Fig. 7. HAULOTTE nacelle



Fig. 8. CASE front loader

- Resulting oversized rocks are broken with hammers or by blasting;
- Resulting salt is loaded using the front loader type STALOWA VOLA/ JCB/ CASE (Fig. 7) into 10t AUSA type dumpers (Fig. 8);



Fig. 8. AUSA dumper



Fig. 9. Rolling collector equipped with grill, mesh size 0.40 X 0.40 m

- Salt is transported to the rolling collector equipped with grill, mesh size 0,40 x 0,40m (Fig. 9.) through which it is discharged and transported to the surface;

For ensuring the continuity of the extraction process, the exploitation activity is performed concurrently in at least 3 exploitation chambers, in each one being performed a distinct work phase, according to the methodology described before.

Quantity of salt resulting from a cycle is:

20m x 12 m x 1.8 m x 2.16 (t/mc, spec. weight) = 933.12 tons

20m x 10 m x 1.8 m x 2.16 (t/mc, spec. weight) = 777.60 tons.

### 2.3. Small chambers and abandoned square pillars, with straight roof mining method

The exploitation method is in compliance with the framework project developed by MINESA - I.C.P.M. Cluj and has the following characteristics:

- Roof (pillar) of the salt deposit has a minimum of 30 m thickness;
- Floor pillar of the salt deposit has a minimum of 10 m thickness;
- Marginal pillars range depending in the exploitation depth, from 22m (for h=80-120 m) to 29m (for h=280-400m);
- Pillars (roofs) between horizons have a min. 8m thickness for a depth of 80-100m and 10m for 280m depth.
- Pillars between chambers are prisms with square base (10-18m), 8m height, the dimensions of the base increasing once with the exploitation depth
- Exploitation chambers have a straight roof, width of 12-16m, height of 8 m and length of 20-300m, depending on the size of the exploitation field;
- Work technology is the following:
- Using the cutter is performed a channel having 1.8m in depth into the floor;
- Workface is perforated (128m) with RIPAMONTI EX-180 perforation installation, mounted on a CATERPILLAR 312 C, executing a number of 185 of blasting holes (40mm diameter);
- Boreholes are loaded with explosive, which is initiated using electrical detonators with ms delay.
- Workface is blasted in single step;
- Workface is ventilated for 1-2 h for exhausting blasting gases;
- Roof and walls of the chamber are lined of the freshly blasted slice and the previous slices are verified;
- Resulting oversized rocks are broken with hammers;

Resulting salt is loaded using the front loader type LIEBHERR 541 into dumpers and is directly transported to the processing installation;

Quantity of salt resulting from a cycle is:

16m x 8 m x 1.8 m x 2.16 (t/mc, spec. weight) = 497.66 tons

#### *2.4. Proposed mining method with small chambers and square pillars and shearer cutting*

This mining method proposed to be applied is with small directional chambers and square pillars, with straight roof, with descending mining, cutting with the point-driven shearer (Pasculescu et. al, 2015a, and Pasculescu et al., 2015b), loading into mining dumpers with the shearer, auto transportation to the surface.

Chambers and mined integrally from a single positioning of the shearer, into a 5m height and 8m width slice.

The main phases of salt extraction are:

- Performing the directional ventilation gallery (Suvar et. al, 2014; Suvar et. al., 2012) (approx. 1.6-2.0 km on w wing of the deposit) to the margin of the horizon's exploitation field, at the limit of the pillar and putting the ventilation under the mine's general depression;
- Performing the cross-sectional preparation gallery for the exploitation panel to the perimeter limit and putting it under the general depression;
- Cutting salt form opening and preparation works is performed using the point-driven shearer and it is loaded with the shearer in mining dumpers;
- After cutting and exhausting salt from the galleries and/or chambers, roofs are lined so that not to remain any unstable surfaces;
- All digging/cutting works shall be executed under the control of the deposit, the identification/determination of perimeter pillars limit.

Advantages of this mining method are the following:

- Easy performance of the mining exploitation structure, as well as easy leading and monitoring mining works;
- Early identification of solutions required by changes occurred within the deposit during the works;
- Ensuring the control and protection of the deposit, of the performed mining works;
- Easy control of the mine structure;
- Reducing to minimum the possibility of execution mistakes, knowing and respecting the coaxial character of the pillars from the chambers and the crossing of protection pillars;
- By removing blasting, disappear faults occurring within the salt massif.

The point-driven shearer has cutting ends rotating transversally. The cutting arm pivots horizontally over the workface. Once the cutting heads penetrate the workface, the cutting depth is set (Pasculescu et al., 2012; Pasculescu et al., 2014).

Before every horizontal cutting, the cutting head is set up for the cutting thickness, penetrating the front over an additional depth. The cutting depth and thickness are determined depending on the physical and mechanical characteristics of the salt.

Workface penetration is carried out by adjusting the arm or movement of the shearer, while the cutting arm pivots horizontally.

The loading mass, during cutting, has to be located on the floor in order to load the salt while the shearer advances. After the initial penetration of the workface, by the movement of the arm is cut a channel on the floor over the entire cutting length and the cutting thickness is set and the arm is pivoted horizontally.

This new salt mining method by cutting with the shearer is successfully used in a series of European mines, such as: Spain-Iberpotad (potassium mine), Poland Polkowice-Sieroszewice, Bulgaria etc.

### **3. Conclusions**

Currently, in Romania and used three underground salt mining methods, namely:

- Small chambers and square bunk pillars mining method;
- Small chambers and square pillars mining method;
- Small chambers and rectangular bunk pillars mining method.

Praid salt mine applies two mining methods, namely:

- Small chambers and square pillars mining method. This mining method is used in Telegdy sector.
- Small chambers and rectangular bunk pillars mining method. This method is used in the New Mine sector.

Using the shearer for mining salt is proper for deep mining, and would substantially improve the mining climate, also the physical productivity, and the biggest advantage would be the almost complete removal of the seismic effect in the pillars.

Besides underground salt mining, salt is also exploited using the humid method in Ocna Mures, Tg. Ocna, Cacica and Ocnele Mari.



## References

- Chiuzan, E., *Solving the ventilation network of Praid salt mine*, Doctoral Thesis Report no. 2, University of Petroșani, Romania, (2018).
- Cioclea, D., Gaman, G.A., Gherghe, I., Radoi, F., Boanta, C., Pasculescu, V.M., *Possibilities to priorly establish the structure of ventilation networks affected by underground explosions*, *24th International Mining Congress and Exhibition of Turkey*, pp. 991-997, Antalya, Turkey, (2015).
- Cioclea, D., Toth, I., Gherghe, I., Tomescu, C., Suvar, M.C., Pasculescu, V.M., *Analysis of transitory phenomena generated by underground explosions upon the ventilation networks*, *Environmental Engineering and Management Journal*, Vol. 13, No. 11, pp. 1401-1407, (2014).
- Covaci, S., Oncioiu, G., Cozma, E., Bădulescu, D., *Underground mining*, (in Romanian), Corvin publishing house, Deva, Romania, (1999).
- Fodor, D., *Exploitation of salt deposits in Romania*, (in Romanian), Engineering Universe magazine, no. 4/2015, AGIR Publishing House, Bucharest, Romania (2015).
- Leba, M., Ionica, A., Dobra, R., Pasculescu, V.M., *Quality function deployment (QFD) based expert system for renewable energy structures. A wind turbine case study*, *Environmental Engineering and Management Journal*, Vol. 13, No. 6, pp. 1365-1370, (2014).
- ICPM Cluj Projects, *Exploitation methods applied for Praid mine salt deposits*, (in Romanian), (1986-2014).
- Oprina, C.A., *Possibilities for mining deep salt deposits*, (in Romanian), Doctoral thesis, University of Petrosani, Romania, 2015
- Popa, A., Răscolean, I., Arad, V., Gâf-Deac I., *Mining exploitation*, (in Romanian), Didactical and pedagogical publishing house, Bucharest, Romania, (1993).
- Pasculescu, D., Lupu, L., Pasculescu, V., Inisconi, I., Suvar, M., *Study of electrocution hazards in three-phase electrical networks with ground-isolated neutral point*, *Environmental Engineering and Management Journal*, Vol. 11, No. 7, pp. 1267-1271, (2012).
- Pasculescu, V.M., Pricop, D.G., Morar, M.S., Florea V.A., *Research on the development of an expert system for selecting technical equipment intended to be used in potentially explosive atmospheres*, *15th International Multidisciplinary Scientific Geoconference (SGEM), Informatics, Geoinformatics and Remote Sensing*, Vol. I, pp. 291-298, Albena, Bulgaria, (2015).
- Pasculescu, V.M., Suvar, M.C., Vlasin, N.L., Gaman, G.A., Florea, D., *Computer modelling of flammable gas dispersion through leakages occurred in technological installations*, *15th International Multidisciplinary Scientific Geoconference (SGEM), Informatics, Geoinformatics and Remote Sensing*, Vol. I, pp. 77-84, Albena, Bulgaria, (2015).
- Pasculescu, V.M., Radu, S.M., Ghicioi, E., Pasculescu, D., Niculescu, T., *Assessing the safety level of technical equipment operating in potentially explosive atmospheres by using computer modelling*, *14th International Multidisciplinary Scientific Geoconference (SGEM), Geoconference on Informatics, Geoinformatics and Remote Sensing*, Vol. I, pp. 43-50, Albena, Bulgaria, (2014).
- Suvar, M.C., Lupu, C., Arad, V., Cioclea, D., Pasculescu V.M., Mija, N., *Computerized simulation of mine ventilation networks for sustainable decision making process*, *Environmental Engineering and Management Journal*, Vol. 13, No. 6, pp. 1445-1451, (2014).
- Suvar, M., Cioclea, D., Gherghe, I., Pasculescu, V., *Advanced software for mine ventilation networks solving*, *Environmental Engineering and Management Journal*, Vol. 11, No. 7, pp. 1235-1239, (2012).
- Tamas, D., Lupu, C., Ghicioi, E., Cioclea, D., Chiuzan, E., *Characterization of the gas emission regime from Praid salt mine*, *Science and Technologies in Geology, Exploration and Mining*, *15th International Multidisciplinary Scientific Geoconference (SGEM)*, Vol. I, pp. 289-295, Albena, Bulgaria, (2013).

# Underground environment optimization using specialized programs

Morar Marius Simion <sup>a\*</sup>, Cioclea Doru<sup>a</sup>, Cioara Cristian Raul<sup>a</sup>, Păsculescu Vlad Mihai <sup>a</sup>

*National Institute for Research and Development in Mine Safety and Protection to Explosion, INSEMEX, 32-34 G-ral Vasile Milea street, Petroșani, 332047, Romania*

---

## Abstract

Worldwide consumption of raw materials is growing, this is due to the explosive growth of population, and the industrial development in certain regions of the world.

In the process of underground coal mining are utilized a complex network of vertical, horizontal and inclined mine workings with the purpose of extraction, transportation and evacuation to the surface. Associated system of mining works have the air network to ensure the oxygen necessary for workers, diluting explosive gases and/or toxic substances and preparations to evacuate heat and humidity from the underground.

For pumping air flows using special fans, with high capacity, located on the surface in the main ventilation station.

Ventilation mining is an extremely sensitive and complex that encompasses many disciplines in the service of achieving and maintaining security conditions underground.

In this regard solving ventilation networks using specialized programs, is a huge step forward that allows skilled practitioners to view real-time network changes and what is more important, can anticipate any disruptions in the ventilation system.

The fans operation depends on the network parameters aerodynamic ventilation and structures that main station ventilation. Knowledge of specific local network parameters leads to the optimization of air flow distribution.

*Keywords:* optimization, fans, management, ventilation networks, aerodynamic parameters;

---

## 1. Introduction

Ventilation mining is an area extremely sensitive and complex incorporating a multitude of disciplines, in this sense, solving ventilation networks using specialized programs is a huge step forward that allows to view real-time changes in the network.

The network of mining works necessary for exploitation of mineral substances useful presents a high degree of complexity, have different shapes and sections respectively, can attain lengths of tens of kilometers.

In order to obtain optimal conditions of work in the underground has to be ensured through primary protection ventilation. The work of mining ventilation aims to achieve three main objectives:

- Concentration of oxygen, the underground staff required;
- Diluting explosive gas and/or toxic in the network of mining works;
- Acquisition of heat exposure in the network of mining works, due to human activity and geothermal gradient.

For good ventilation at each job level mining is necessary optimized the distribution debits on each branch of the local network.

In this sense it is necessary to resolve network at a mine ventilation.

For this presentation was chosen the ventilation network of the Lonea mining unit and I'm used specialized program 3D Canvent.

The software has a graphical representation of the network ventilation and the quantities involved.

---

\* Morar Marius. Tel.: +40-254-541-621; fax: +40-254-546-277.  
E-mail address: marius.morar@insemex.ro.

## 2. Presentation and solving the ventilation network

The ventilation network of Lonea mining unit is very complex. The ventilation network comprises four routes of entry of fresh air, namely: skip shaft I, skip shaft II, Auxiliary mine shaft located inside and Valea Arsului Shaft located in the central north of the mine. Also have three main stations ventilation namely: the expansion rate of raises 840, Valley of raises ventilation shaft ventilation Valea Arsului and Jieț whilst also includes underground mine arranged across the eight horizons: 250; 300; 350; 400; 440; 460; 500 and 615.

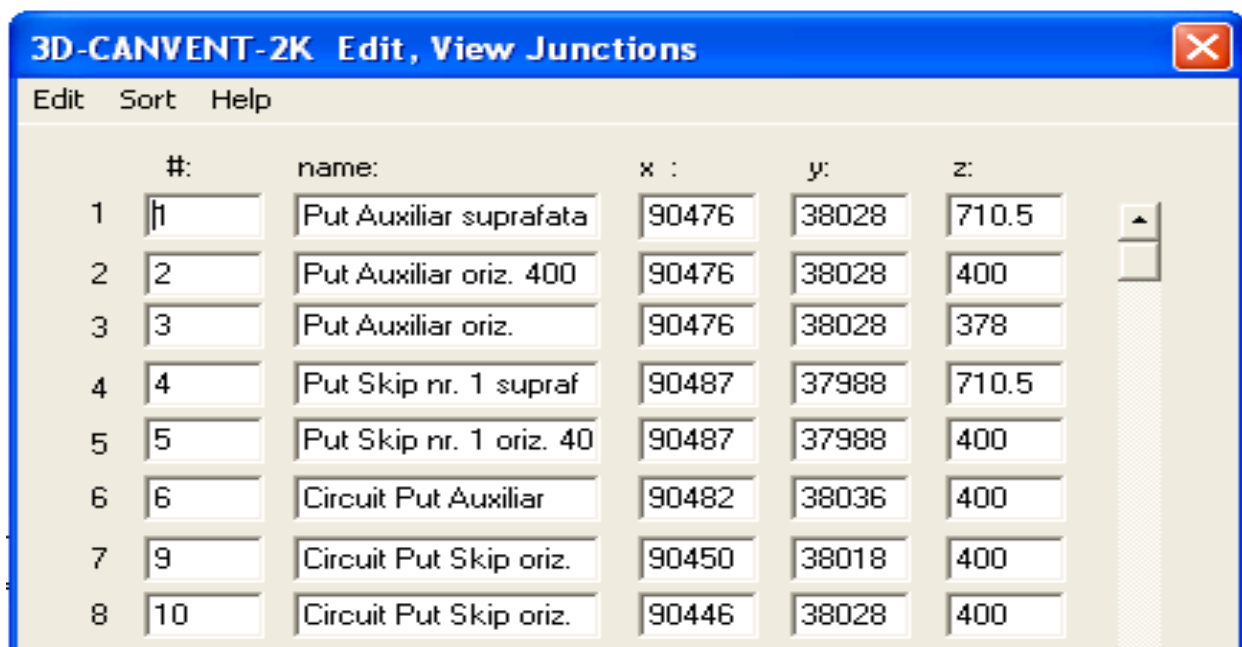
These works consist of main transverse galleries, galleries directional diagonal galleries, galleries cross number, inclined planes, stopes and connecting rising.

The entire ventilation network comprises 339 junctions (nodes) and 424 branches.

For providing the best solution available for such a complex ventilation network, we have used the Hardy-Cross method for successive approximation. This method represents the grounds of expert software CANVENT designed in Canada. This software helped us to provide the solution for the ventilation network as well and optimization of the air flow distribution within the ventilation branches.

Solving the ventilation network related to Lonea mining unit made necessary to run several stages:

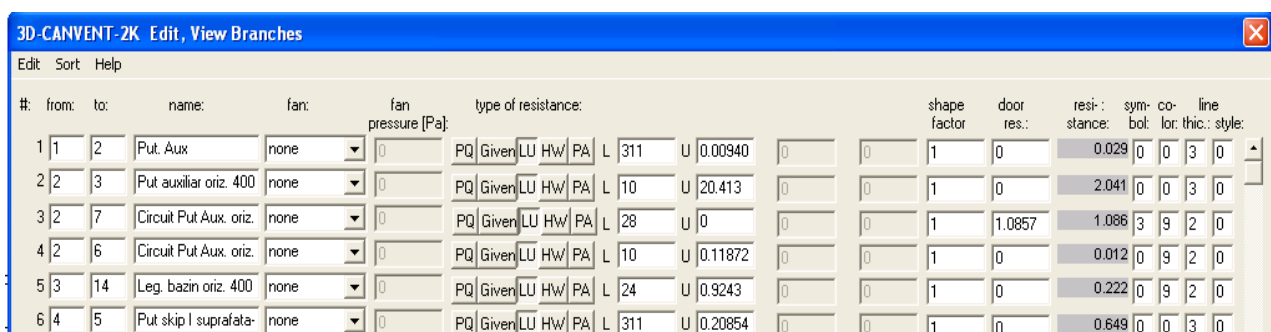
- Marking the junctions of the ventilation network on the spatial diagram;
- Determining the geodesic coordinates of the identified junctions;
- Inputting the geodesic coordinates of junctions and the existing branches into the database of the software (Fig 1);



#:	name:	x :	y:	z:
1	Put Auxiliar suprafata	90476	38028	710.5
2	Put Auxiliar oriz. 400	90476	38028	400
3	Put Auxiliar oriz.	90476	38028	378
4	Put Skip nr. 1 supraf	90487	37988	710.5
5	Put Skip nr. 1 oriz. 40	90487	37988	400
6	Circuit Put Auxiliar	90482	38036	400
7	Circuit Put Skip oriz.	90450	38018	400
8	Circuit Put Skip oriz.	90446	38028	400

Fig. 1. Table with knots

- The carrying out of measurements in situ; these measurements include:
  - measurements of the aerodynamic parameters of mine workings;
  - measurements of the geometrical parameters of mine workings;
  - measurements of the physical parameters of the air.
- Calculation of aerodynamic strength specific to each branch;
- Inputting the values of parameters specific to the ventilation network into the expert software CANVENT (Fig 2);



#:	from:	to:	name:	fan:	fan pressure [Pa]:	type of resistance:	shape factor	door res.:	resi- stance:	sym- bol:	co- lor:	line thic.:	style:
1	1	2	Put. Aux	none	0	PQ Given LU HW PA L 311 U 0.00940	0	0	0.029	0	0	3	0
2	2	3	Put auxiliar oriz. 400	none	0	PQ Given LU HW PA L 10 U 20.413	0	0	2.041	0	0	3	0
3	2	7	Circuit Put Aux. oriz.	none	0	PQ Given LU HW PA L 28 U 0	0	1.0857	1.086	3	9	2	0
4	2	6	Circuit Put Aux. oriz.	none	0	PQ Given LU HW PA L 10 U 0.11872	0	0	0.012	0	9	2	0
5	3	14	Leg. bazin oriz. 400	none	0	PQ Given LU HW PA L 24 U 0.9243	0	0	0.222	0	9	2	0
6	4	5	Put skip I suprafata	none	0	PQ Given LU HW PA L 311 U 0.20854	0	0	0.649	0	0	3	0

Fig. 2. Table with branches

- The 2D or 3D drawing of the ventilation network;
- Balancing the ventilation network;
- Settling the ventilation network. Both the direction and the optimum distribution of the air flows along each branch are being identified in this stage (Fig 3 and 4);
- Getting the results.

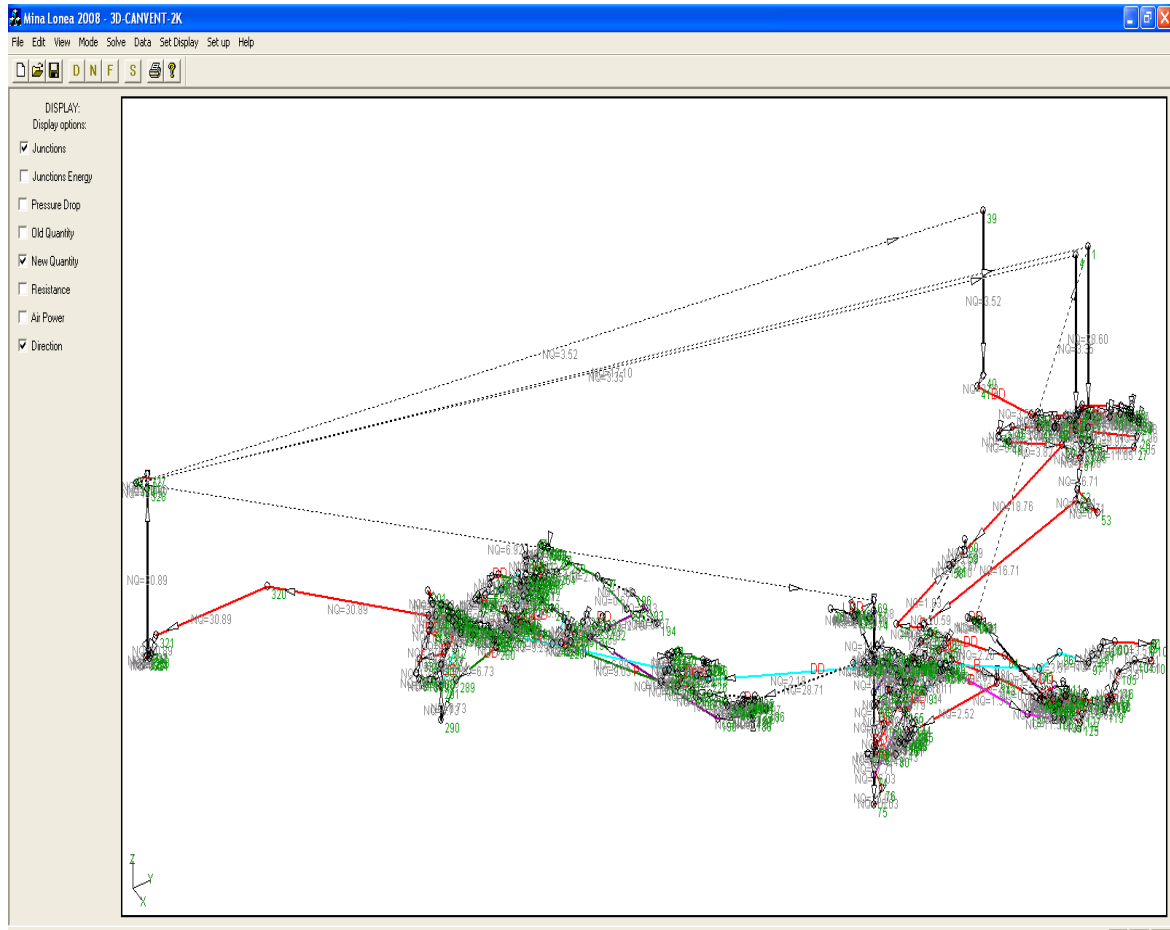


Fig. 3. Ventilation network modeled and solved with 3D Canvent specialized program

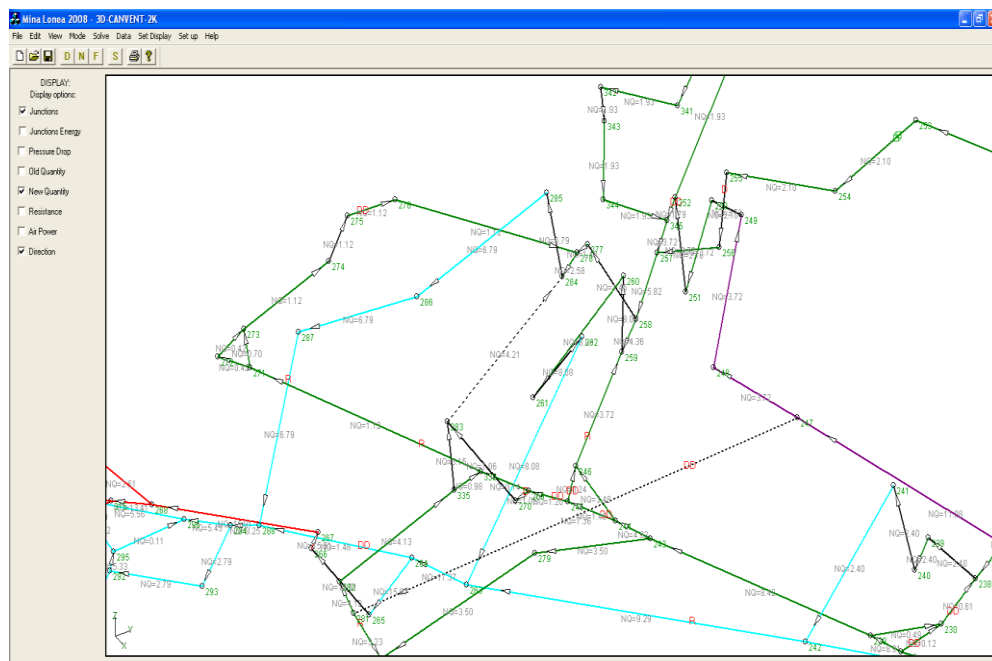


Fig. 4. Detail of ventilation network, modeled and solved with 3D Canvent specialized program

This final stage provides the data on electronic support or paper regarding the graphic settlement of the ventilation network.

After entering all the data related to nodes, branches and fans, it started to solve the mine ventilation network.

In figure no. 5 is presented the introductions of nodes in the ventilation network and in figure no. 6 is presented the results of fan V<sub>1</sub>,  $\alpha = 30^\circ$ .

## 3D-CANVENT-2K

File: Mina Lonea baza - Junction Input

#:	Description:	X:	Y:	Z:
1	Put Auxiliar suprafata	90476.00	38028.00	710.50
2	Put Auxiliar oriz. 400	90476.00	38028.00	400.00
3	Put Auxiliar oriz.	90476.00	38028.00	378.00
4	Put Skip nr. 1 suprafata	90487.00	37988.00	710.50
5	Put Skip nr. 1 oriz. 400	90487.00	37988.00	400.00
6	Circuit Put Auxiliar	90482.00	38036.00	400.00
9	Circuit Put Skip oriz. 400	90450.00	38018.00	400.00
10	Circuit Put Skip oriz. 400	90446.00	38028.00	400.00
11	Bazine apa oriz. 400	90438.00	38034.00	400.00
12	Bazine apa oriz. 400	90488.00	38110.00	400.00
13	Bazine apa oriz. 400	90504.00	38130.00	400.00
14	Bazine apa oriz. 400	90458.00	38039.00	400.00
15	Bazine apa oriz. 400	90486.00	38083.00	400.00
16	Bazine apa oriz. 400	90505.00	38114.00	400.00
17	Bazine apa oriz. 400	90512.00	38124.00	400.00
18	Circuit P A oriz. 400	90506.00	38098.00	400.00
19	Circuit P A oriz. 400	90519.00	38120.00	400.00
20	Circuit P A oriz. 400	90505.00	38070.00	400.00
21	Circuit P A oriz. 400	90531.00	38112.00	400.00
22	Circuit P A oriz. 400	90535.00	38115.00	400.00
23	Circuit P A oriz. 400	90544.00	38128.00	400.00
24	Circuit P A oriz. 400	90554.00	38120.00	400.00
25	Transv. Put Skip Oriz. 400	90500.00	37980.00	400.00
26	Circ. P A- P Skip or. 400	90590.00	38096.00	400.00
27	Circ. P A- P Skip or. 400	90616.00	38072.00	400.00
28	Oriz. 400	90568.00	37984.00	400.00
29	Oriz. 400	90544.00	37991.00	400.00

Fig. 5. Ventilation network nodes

Fan Name:	Branch		Pressure [Pa]:	Quantity [m³/s]:	Air Power [KW]:	Cost [\$]:
	From:	To:				
V1- VOD 2.1 - 30g	fixed	141 142	2683.21	21.06	56.52	390882
		328 329	1311.10	48.54	63.63	440083
	fixed	173 175	2075.22	29.29	60.79	420381

Fig. 6. The results for fans

In figure no. 7 is presented the characteristic curve of fan  $V_1$ ,  $\alpha = 30^\circ$ .

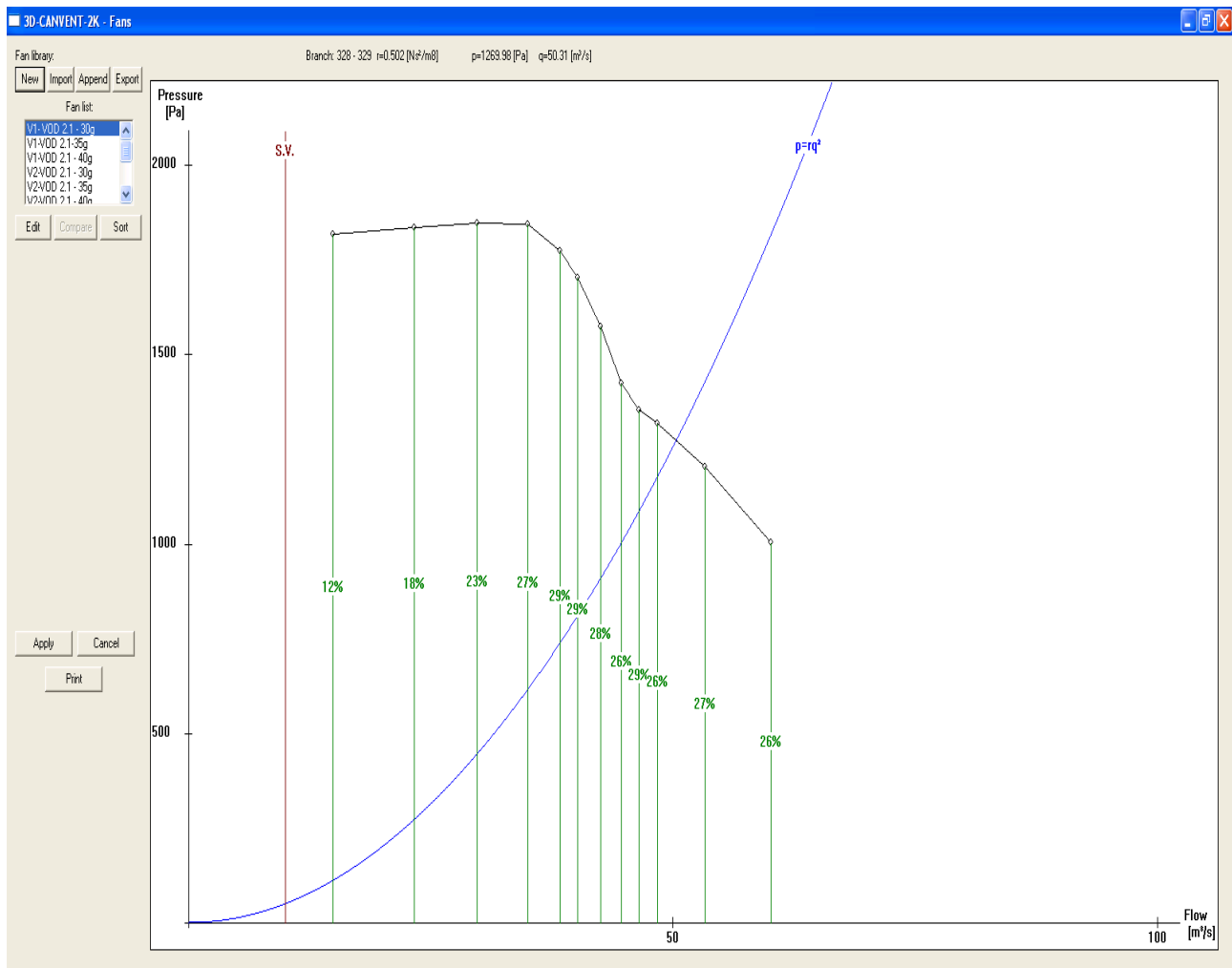


Fig. 7. Fan  $V_1$ ,  $\alpha = 30^\circ$ , characteristic curve

### 3. Conclusions

The ventilation network given as example belongs to Lonea mining unit and includes 4 shafts, 3 ventilation raises, 8 levels and several underground workings (cross-sectional galleries, directional galleries, diagonal galleries, inclines, connection raises and working faces).

The optimization of the underground environment has been accomplished with the 3D Canvent specialized software.

With 3D Canvent, was found the best solution for solving the mining ventilation network.

We have been able to perform simulations on this software that involved certain changes which might come up in the ventilation network.

Giving solutions for the ventilation network with the help of specialized program allows the best possible solutions irrespective of its complexity.

Implementation of the 3D Canvent specialized program afforded effective distribution of air flow rates in each branch and thus a better distribution of air in workplaces and reducing costs through effective distribution of circulated air.

## References

- Baltaretu, R., Teodorescu, C., *Mine ventilation and safety (in Romanian)*, Didactic and Pedagogic Publishing House, Bucharest (1971).
- Cioclea, D., *Solving ventilation network under depresiometric measurements to determine air flow rates, the depressions, the aerodynamic resistance, the job of the EM Lonea (in Romanian)*, INSEMEX Study, (2008).
- Gherghe I., *Service modeling and optimization of ventilation network of EM Lonea (in Romanian)*, INSEMEX Study, (2008).
- Simion, Morar Marius et al, *Updating the ventilation network of Lonea mine unit using dedicated IT software*, 16<sup>th</sup> SGEM GeoConference on Science and Technologies in Geology, Exploration and Mining, (2016).
- Todorescu, C. et al, *Mine ventilation (in Romanian)*, Technical Publishing House Bucharest, (1971)
- 3D CANVENT – *User's manual*
- XXX - *Technical documentation of Lonea mining unit*



# The impact of the integrated technical system on the quality of construction works

Bușe Florian<sup>a\*</sup>, Bușe Gheorghe-Florin<sup>a</sup>

<sup>a</sup>University of Petrosani, 20, University Street, Petrosani, 332006, Romania

---

## Abstract

The integrated technical system consists in the development of a production technology on the path design – execution – testing – experimentation – homologation.

The constructions, as products of human activity, presents a series of characteristics such as: high capital requirements; influenced by a high number of variables, unpredictable due to its long lifetime; has to fulfill the needs of two-three generations which makes standardization difficult and extends the time of experience gathering needed to optimize the products; there are also craft works, despite the technology advancement, where the quality is given by the qualification and skill of the workers; it is difficult to appreciate an optimum ratio between the increase of execution costs for quality improvements and the reduction of the exploitation costs; no defects or scraps are allowed (especially related to stability, resistance, durability and exploitation safety).

An integrated construction system means construction design, works and assembly (material and parts supply, construction equipment, qualified workforce) at European level, according to an established schedule, starting from precise cost calculations which do not modify for the entire contract, etc. The construction integrated system uses an advanced technology and is a complete construction system which provides resistance, durability, excellent thermic isolation and sound protection. The result is a predictable and efficient product considering both the used resources and the implied costs.

The integrated technical system provides maximum efficiency of the maintenance costs on the entire lifetime of the construction, ensuring substantial cost saves regarding energy, repairs of design modification.

**Keywords:** integrated technical system, construction integrated technical system, construction works, construction quality, technical efficiency of construction equipment;

---

## 1. Introduction

An integrated technical system consists in creating a partnership network composed of organization systems from the domains of research, technology development and innovation, mechanical technologies in constructions, chemical technologies in constructions, mechanical systems execution in constructions, pneumatic-hydraulic systems execution, electronic and automatization systems execution for the development of a technologic line towards achieving a product with industrial applications in constructions.

The most quality characteristics are imprinted to the project in the design stage. These are less expensive and easy to modify or replace. In the design stage there can be reviewed certain ideas from the conception stage without significant additional expenses (Bușe, 2017).

Having the right materials and equipment at the quality levels suggested in the design stage removes the risk of getting a low quality product (Ilieș and Crișan, 2008).

The execution stage may contribute to keeping, improving or lowering the project quality. If we have a good design documentation, following all the prescriptions leads to a good project quality, while disrespecting these data leads to a lower quality project. A project with quality deficiencies may be improved if, during the execution, the inconsistencies which lead to this lower quality are traced, and there are suggested modifications of the design documentation which to improve the project quality. One of the most important stages for configuring the quality of a future project is the maintenance stage where we may follow the project operation and the implications of the possible quality deficiencies (Toma and Margarit, 2002).

---

\* Bușe Florian.  
E-mail address: prof\_buse@yahoo.com



All the deviations from the required quality of a project lead to additional costs, lower or higher depending on the stage when the deviations are solved (Zafiu and Gaidoş, 2001).

## 2. The integrated technical system in constructions

The integrated system in constructions represents the most advanced technology in construction systems, giving all the benefits required by a modern technology, design of the most advanced standards. Various design options, high level resistance and excellent capacity of energy loss isolation make from the integrated system in constructions an important technology for present and future constructions.

An important role in keeping the designer requirements and their retrieval in construction quality is given by the integrated or applied technical system (TS). It has to create the balance between the used resources and the performance of the construction, expressed by the methods of evaluating the results of the construction production process (CPP) (fig. 1): work and, consequently, construction quality, production expenses, work execution deadlines, environmental impact, security requirements fulfillment, work protection and safety.

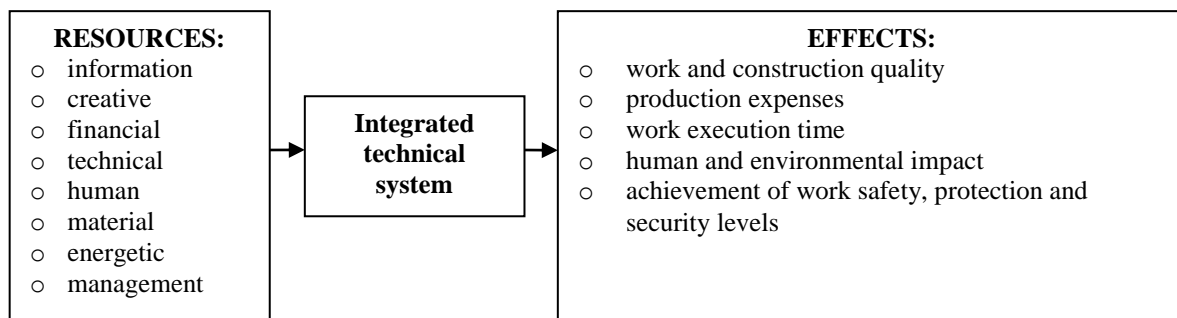


Fig. 1. Construction production process

The integrated TS is determined by the interdependences between the factors from every CPP component (fig. 2): technology and metrology equipments, materials and energy resources, human factors, technology procedures applied, environmental factors.

If we refer to construction quality, we may consider that it covers, due to the integrated TS, the quality of every factor. As it results from the diagram type cause-effect (fig. 3), named also Ishikawa diagram (fishbone diagram), neglecting the quality of any of these factors up to a certain degree will affect the quality of the construction (Zafiu, 2004).

Next we will analyze shortly the main factors of the TS: technologic equipment, materials, human factors and technology procedures.

The term "technologic equipment" usually refers to the technical endowment used for construction executions represented mostly by technical machines.

No construction activity can take place without the required technical equipment. There are some work categories where the technical processes and its results depend entirely on the capacity of the used equipments, such as concrete works, roads or railroads, etc. Therefore, the problem of the construction technical equipment becomes extremely complex, being connected to the applied procedures and having a large set of specific importance.

Therefore, we consider the requirements for performance level ensured by the technical equipment on two basic trends:

- The fidelity of ensuring the technical quality for the processed and used materials, respectively their capacity of executing specific works in their domain, at the quality level for construction technical requirements;
- The reliability and maintainability, operation safety, ergonomic qualities and environmental protection quality.

Each of the above aspects are found directly or indirectly in the quality of the construction.

It is obvious that the fidelity of ensuring the technical quality for the processed and used material is found directly in the quality of the construction. Especially since it is known that the technical equipment is involved directly in the two components of the construction production process (fig. 2): the processing of materials and construction components in industrial units specialized for production and using them in site works for construction execution.

The low reliability and maintainability influence the construction quality as a result of breaking the normal development of the technical process, which may lead to the impossibility of keeping under control the quality parameters of the work or to the work depreciation in time.

The lack of operation safety may lead to failures which don't affect only the development of the technical process by temporary breakdowns with negative effects on quality, but also lead to partial depreciations of the construction, which will have to be repaired.

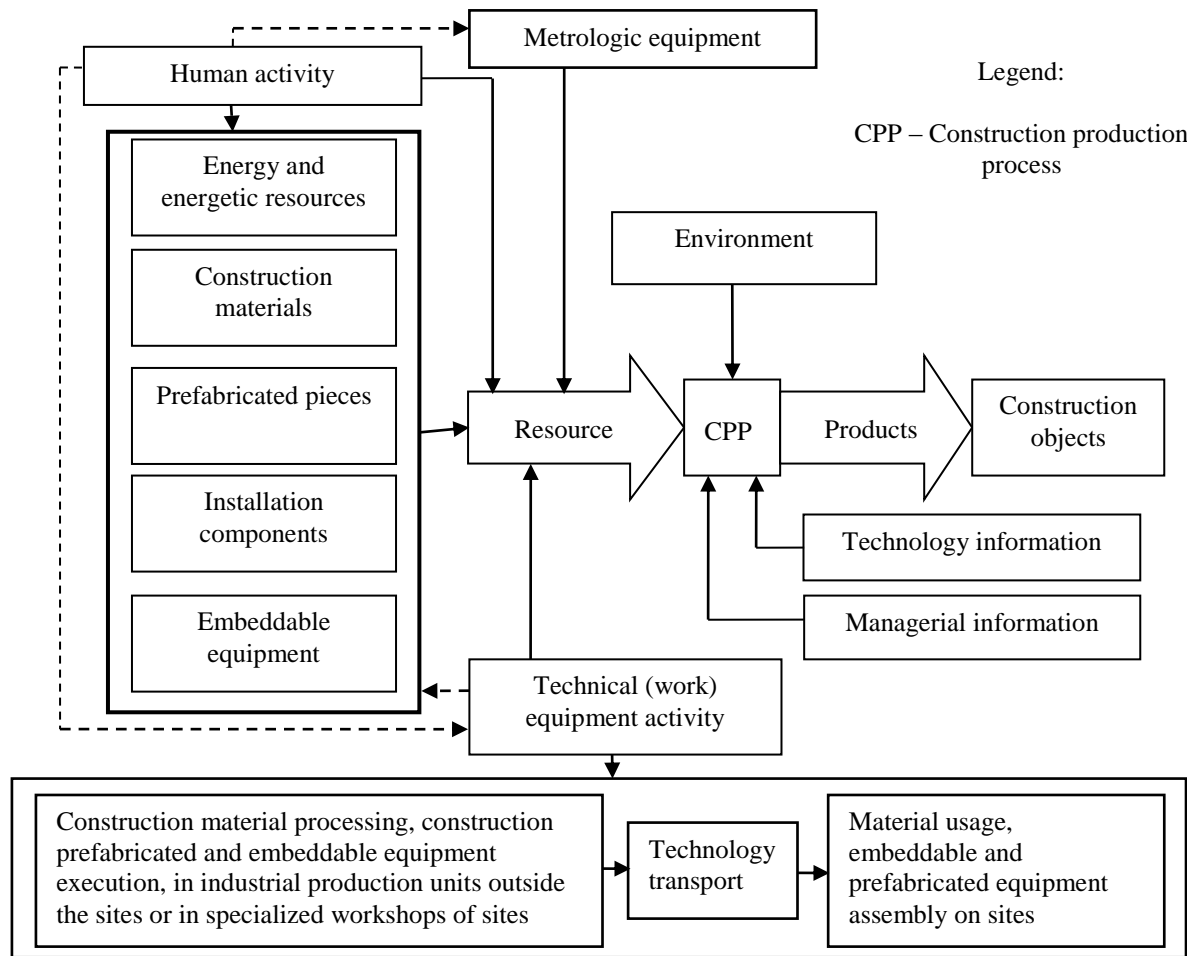


Fig. 2. System factors of every CPP component

This presumes that the technical equipment are permanently maintained, repaired and modernized in order to match the requirements and guarantee the operation safety at nominal parameters.

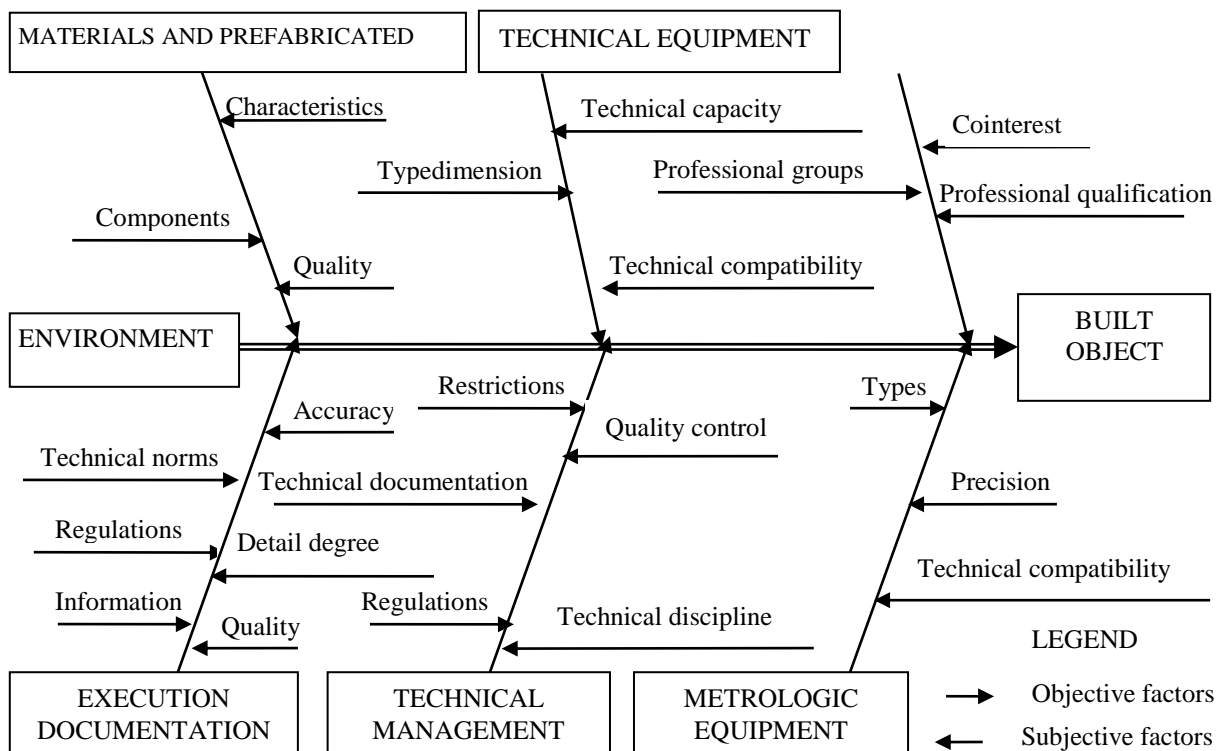


Fig. 3. Cause-effect type diagram

Ergonomic and environmental protection features act indirectly through the human factor, subject of stressing requests with negative effect on the quality of the technical process development and, consequently, on the quality of the construction.

The practical implementation of these requirements is done through a series of actions which consists in the work on the technical documentation and specific regulations:

- the instructions of putting into operation of the equipment, taking into account their complexity, working regime, work nature and other specific factors;
- the instructions for protection, grinding and operation, and also for adjusting to normal parameters;
- the greasing schemes and the maintenance and repairing instructions for technical equipment;
- the procedures for equipment disposal by retrieving and reusing the components;
- the technology for repairing, refurbishing and reusing the used parts
- the technology for reusing other materials resulted from dismemberment.

These issues are part of the terotechnics and terotechnology domain.

### 3. The use of terotechnics and terotechnology in constructions

Terotechnics is the multidisciplinary science which deals with the complex of actions done to ensure the operation at nominal parameters and in safe conditions of the technical equipments, passing through the entire cycle from conception to recycling (fig. 4).

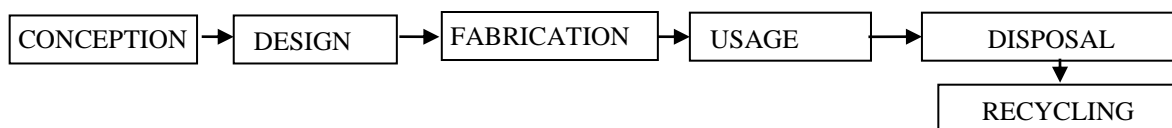


Fig. 4. Technical equipment cycle

Terotechnics deals with the specific matters known as: reliability, maintainability, tribotechnics, ecology and environment, mechanic-energetic design and ergonomomy.

Terotechnology deals with applying the organization variants for maintenance, repairing and upgrading the technical equipment and takes into consideration their selection criteria, for reducing the stationary times and intervention costs, by technology preparation in advance and ensuring new or refurbished spare parts (Zafiu, 2005).

Specific regulations are needed furthermore, for getting the desired quality in construction through technical equipment, both regarding its implication in work and by ensuring the normal operation and exploitation conditions on site. The specialists in the field of construction technical equipment agree that their technical certification is the activity which confirms the technical capacity of the equipments to perform quality works and to fulfill the safety requirements, so the work can be done in safe conditions and the technical processes at the required quality level. Surely, the concepts of performance and quality cannot exist without the basic requirements from the regulated domain regarding work security, safety and protection for men, but also in the domain of environmental protection, for construction works where technical equipment has a decisive role (Antohe, 2004).

Therefore, we support the need to further develop some authorized organizations, who can perform the generic activity of "technical certification".

The control activity for technical certification of technical equipments in construction takes place according to the regulations in the construction quality field, on three main directions which ensure their operation: user security and protection control, environmental security and protection control, work quality capacity control.

The certification of the technical capacity of construction equipment is done by:

- the conformity certification for new equipment without CE mark;
- technical inspection for the equipment kept in operation after passing the standard lifetime or for second-hand acquisitions.

Current concept improvements of the technical equipment structure lead to constructive solutions which allowed the use of board computers and automatic regulation systems of functional parameters, such as:

- the implementation of sensors, to give information on environment and equipment condition;
- the use of information processing and interpretation resources;
- the introduction of artificial intelligence in equipment lead systems.

This was occasioned by the generalization of hydrostatic actions and was concretized by:

- automatic regulation of work parameters of hydrostatic pumps depending on the work equipment opposition, in order to keep the motor moment constant;
- automatic commanding through the board computer of the work technical parameters, not depending on the machine position;
- the association of some measurement and control devices (MCD) with construction installations, both for the continuous regulation of some work parameters and for the automatic control of work quality;
- the assurance of preventive maintenance through integrated, operational systems which to evaluate continuously the technical condition of the machine.

Taking into consideration the CPP characteristics, the design of technical equipment has to keep in mind, beside the negative effects of the operation environment, a series of constructive particularities:

- the high degree of mobility on site;
- the difficulties in providing the command execution precision;
- the intense interaction between the equipment and environment, to help locating the work areas, etc.;
- the need of superior specialization of operation through intense training;
- the conceiving of the man-machine interference, depending on site specifics;
- the distinction of particularities depending on the work conditions: temperature, dust, humidity, rain, wind, shocks, vibrations.

Therefore, there are three main factors in order to ensure the technical conditions for equipment use:

- the workforce quality – the more advanced are the equipment the more skilled has to be the mechanics, both for operation and for maintenance;
- the processed materials quality – the technical compatibility between the equipment and the processed material properties;
- the work conditions – keeping minimal work conditions for processes, according to the requirements from the equipment use technical instructions.

#### **4. The role of technical project in construction execution**

The technical project (THP) aims to create the technical-economic documentation for construction execution which will basically solve the following issues (Zafiu et al, 2004):

- the analysis of the technical process and finding mechanization alternatives;
- the selection of the mechanized alternative for the construction-assembly works (C+A), based on the technical-economic indicators and pointing out the backup alternatives;
- the choice / design of the auxiliary devices used;
- the elaboration of technologic plans for work mechanization and the technologic files on basic activities and complex processes;
- the schedule of mechanized execution of construction works considering the resources needed and their technologic usage, but also the schedule optimization in order to fit the technical-economic parameters of the works;
- the elaboration of the requirements regarding work safety, work and environmental protection.

THP will be done in order to give the technical information needed for the general coordination of construction works through project management, quality management and safety, work and environmental protection management.

THP is the main documentation source for the elaboration of procedures from the quality manuals, but also for the other documents needed to implement the construction quality system.

The execution details (ED) are part of the technical project (TP) and represents the documentation given by the designers, needed to clarify constructive details so the construction to fulfill all the parameters according to the project, legislation and construction certification.

Through THP the objective and the nearby constructions can be traced, during work execution. THP has to follow all the TP requirements and the ED regarding the work quality control and, if necessary, to extend by introducing additional controls.

In order to guarantee a safe, quality construction, the THP has to provide activities regarding the work execution surveillance and technical quality control, during the execution process.

THP provides the norms to be followed in work execution, having in mind the following requirements: personnel safety, location safety, execution procedure safety, technical equipment operation safety.

THP will give technical solutions and will make recommendations in order to reduce, during the construction works, the effects on the environment caused by: noise, terrain vibrations, air pollution, surface water pollution, underground water pollution, ground pollution.

In order to supervise the construction process and the execution quality, there will be established:

- the validity of design hypothesis;
- the identification of the differences between real terrain conditions and design conditions;
- the detailed planning of actions in order to establish if the construction works are done according to the THP and to the technical regulations in the field.

The level and quality of the surveillance and monitoring has to be at least the ones in the project, according to the safety parameters and coefficients.

There will be identified the elements which were the base for the project development and were influenced by the surveillance and monitoring activities.

The inspection, control and field and lab tests requested by the technical process surveillance and by monitoring the construction behavior during works must be established together with the THP development, which should include a „Program for the quality insurance of the execution”.

The THP development should consider the aspects from the technical certifications, issued by certification organizations, given to certain technical equipment, materials and procedures, which fulfill the norms of certification procedures. The THP is written by the constructor, depending on his technical endowment and the workforce needed. The following aspects are taken into consideration: the ease of work execution, fitting the scheduled costs, respecting the execution schedule, respecting the imposed quality norms. The specialized technical personnel who takes place to THP development should be certified by professional authorities (Ceașu, 1992). Respecting the technical documentation for execution should be stated clearly in the THP.

## 5. Conclusions

The construction quality should have a complex scientific approach, since the implications of low quality are bigger compared to other products.

The construction quality is not only a problem of the constructor, it is a national problem and lately European or worldwide problem. Therefore, the E.U. assigned the European Committee for Standardization to establish norms which to acknowledge the organizations and labs which certify quality in all member states.

The total quality management system targets all the aspects of company activity and states quality as strategic element.

The total quality management strategy is materialized in the integrated effort at all company levels in order to increase the client satisfaction through continuous practical improvements.

The paper presents the quality importance for constructions, the causes of lower quality, the quality cycle and the quality system in construction. At the end there are described the information sources, the methods and technics used in quality planning, insurance and control for construction works.

## References

- Antohe, G., *Quality insurance and exploitation safety of the construction products and equipment by evaluating the compliance with basic norms*, AROTEM Monitor, year 8, no. 2, april-june, (2004).
- Bușe, Gh. F., *Production systems engineering*, Universitas Publishing, Petroșani, (2017).
- Ceașu, I., *Managerial Encyclopedia*, ATTR Publishing, (1992).
- Ilieș, L, Crișan, E., *Company logistic management*, Risoprint Publishing, Cluj-Napoca, (2008).
- Toma, M., Margarit, N., *Construction management – The planning and organization of construction works*, Economic Publishing, București, (2002).
- Zafiu, Gh. P., Gaidoș, A., *Technical resources engineering and management in constructions*, MATRIX ROM Publishing, București, (2001).
- Zafiu, Gh. P., *The quality of constructions in relation with the performance of the equipment and technical processes*, The experience exchange of construction labs - SELC – XVI<sup>th</sup> edition, Neptun 07 - 09.10/2004, (2004).
- Zafiu, Gh. P., *Integrated technical system. The impact on the quality of the construction works*, Construction magazine, october, pp. 112-114, 116, 118, (2005).
- Zafiu, Gh. P., Șoimușan, V., Gaidoș, A., Tonciu, O., Rizea, Cl., *Documentary on technical project development for constructions*, MTCT, (2004).

## Efficiency of industrial ventilation installations

Rădoi Florin<sup>a\*</sup>, Gherghe Ion<sup>a</sup>, Chiuza Emeric<sup>a</sup>, Matei Adrian<sup>a</sup>, Drăgoescu Răzvan<sup>a</sup>

<sup>a</sup>National Institute for Research and Development in Mine Safety and Protection to Explosion, INSEMEX, 32-34 G-ral Vasile Milea street, Petroșani, 332047, Romania

---

### Abstract

Effective and efficient air distribution is an important aspect of industrial ventilation.

When the air flows through a ventilation column, the pressure required to push or draw air through it, depends not only on the internal frictional force but also on the dimensions, length and shape of the pipe, the roughness of its walls, the nature of the obstructions inside, speed and air density.

The air movement introduced into ventilated rooms can be controlled and conducted as direction and sense of movement. In rooms, overpressure or under pressure may be created as necessary.

Designing and building an individual ventilation system, should harmonize comfort requirements with the user's ventilation system management, without adversely affecting other system functions.

*Keywords:* ventilation, optimization, efficiency;

---

### 1. Introduction

The quality of the environment in which the staff perform their activity has a complex influence on them, both in terms of microclimate conditions and in labour productivity.

For many categories of premises, where significant disasters occur (production rooms, laboratories, etc.), the quality of the environment cannot be guaranteed only by the heating system. In order to remove toxic odours, there is a need for a "controlled" introduction of airflow. The nature and amount of harmful emissions, their mode of propagation, the building system of the enclosures, the values at which indoor air parameters are prescribed for comfort or technological reasons, the admissible limits to which the concentrations of various harmful substances must be reduced, have led to the use of a wide range of industrial ventilation facilities.

Industrial ventilation systems have a great diversity in terms of composition, (Doru C., et al., 2013) equipment fitting, component type, size of installations according to the volume of air flow rates, thermal (heating or cooling) power and generated pressures, as well as the way of air exchange in rooms, the temperature, pressure and humidity levels achieved in the rooms.

The type of building to which an industrial ventilation plant is intended is given its specific imprint on the installation, in particular through the solution adopted, the technical design (appearance, route, leakage, parameter assurance, noise level, automation, operation and maintenance etc.).

Automatic regulation installations for industrial ventilation facilities ensure that the indoor air parameters (temperature, relative humidity, air speed, CO<sub>2</sub> concentration) are preserved at any time of the year. Automatic adjustment is required for economic reasons, but also because manual adjustment of various parameters is not possible. Automation installations regulate the heat flow (hot / hot water, chilled water, steam) that feeds the heat exchangers of the air handling units (heating batteries, cooling batteries) or the airflow rate of the installation (fresh air, air recirculated, exhaust air).

### 2. Applicable ventilation systems

The adopted ventilation system must take account of the technological process, (Rădoi F., et al., 2016) density of sources, and propagation of harmful agents and the intensity of harmful agent's release.

---

\* Rădoi Florin. Tel.: +40-254-541-621; fax: +40-254-546-277.  
E-mail address: florin.radoi@insemex.ro.

Systematic natural ventilation – in case of heated workshops without a release of noxious vapours, gases or dust with high heat releases and less releases of moisture, mainly applied in the form of mixed ventilation or along with other systems.

General exchange mechanical ventilation – applied when it occurs a release of harmful substances and the systematic natural ventilation is insufficient.

Local exhaust ventilation – used in order to improve working conditions in certain areas adjacent to sources of heat, strong radiant sources or to prevent entry of cold air through exterior doors.

Local air intake ventilation - when there are concentrated sources of harmful releases and general ventilation is insufficient even in large volumes of air.

Local absorption and exhaust ventilation - for example in industrial ablutions.

Emergency ventilation - automatically turns on in case of large accidental releases of harmful substances occurrence as a result of technological equipment failures.

Industrial air-conditioning- is required by the manufacturing processes, the need for precise conditions, in case of high precision processing, testing, and calibration.

### 3. Optimization of industrial ventilation installations

The problem of industrial ventilation has risen due to the serious pollution problems of both the industrial areas (and their surrounding areas) and the industrial premises. It is obvious that before addressing an industrial ventilation study, the question is whether there is no simpler means of suppressing the causes of pollution or of reducing pollution by modifying the production process or the design of the industrial plant. It is preferable to treat the causes that lead to pollution and thus to eliminate it even from the design, and only when this is not perfectly possible, it is necessary to limit the effects of the pollution.

In order to be able to choose the correct ventilation system, (Alexandru Cristea, 1971) a complete analysis of the workplace to be ventilated must be carried out, so that the solution chosen to not only fix the problem of the exhaust, but also to be well received by the user, respecting the thermal comfort of it.

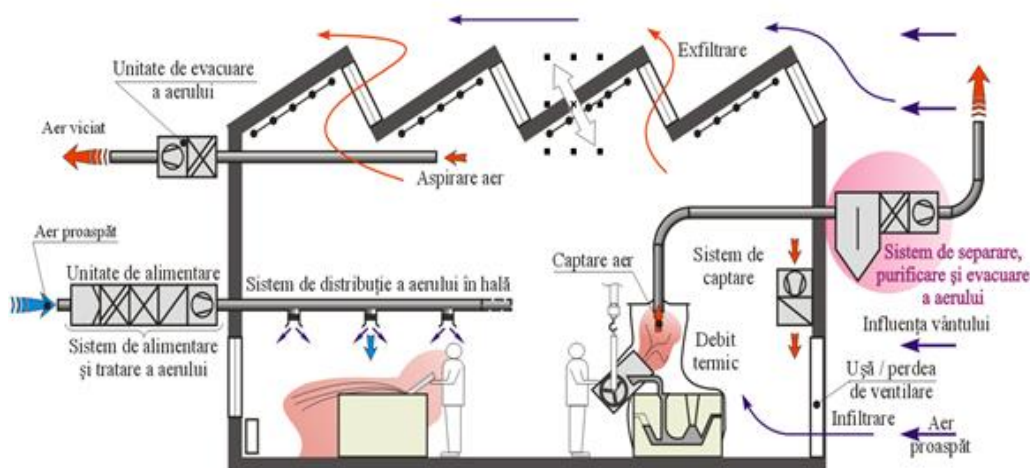


Fig. 1. Schematic diagram of an industrial enclosure

Thus, in an industrial area, the comfort of the workplace is influenced by the following factors:

- the presence of an air stream;
- an acceptable temperature gradient;
- soil temperature (too low or too high);
- the existence of an asymmetric radiant heat field, due to the presence of cold windows, heat sources only by one part of the operator's body or relative humidity level.

Choosing an industrial ventilation solution can be done by completing the following sequence of steps:

- clear definition of the building and its working stations, (Matei, I., et al., 2000) the type of industrial process being carried out, the personnel employed, the environmental restrictions, the temperature and the conditions for keeping the building in good condition;
- determination and classification of sources of pollution, their physical and chemical characteristics;
- the choice of the technical solution for capture and ventilation, considering: the possible evolutions of the industrial process and the changes that these developments can bring with regard to the ventilation system and the possible incompatibilities between different pollutants (e.g. dust and humidity, acids and bases, etc.) that require their separation;
- determination of parameters (air velocity, flow, heating) and calculation of the installation (determination of losses, load, diameter, installed power, etc.), choice of circuit elements (air inlets, required piping, fans, automatic, etc.), the physical location of the component parts, commissioning, reference values, maintenance;

- the ventilation scheme adopted must ensure that the air moves in the sense of harmful propagation;
- the collection and disposal of harmful substances at the site where they occur (use of local absorption plants in the case of concentrated poisons or the provision of emergency facilities in case of accidental leakage of toxic substances), in order to avoid their spread;
- introducing fresh air as close as possible to people's work area, respectively the ventilation system ensures uniformity of air parameters throughout the room in order to avoid clutter of harmful substances;
- use of overpressure or depression to limit the spread of noxious substances in or from other rooms or to avoid cold air drafts.

The selection and sizing of air intake and outlet holes, (Olga Bancea, 2009) is very important to ensure comfort conditions or working conditions and production processes and has two stages:

- ensure a good air circulation in the room so that air can be treated at all points, there are no areas where the air stagnates, no overheating air, air movement will not lead to the spread of noises, etc. The movement of air in a room takes place depending on the location of the inlet and outlet holes. Movement of air must be done at the same time, in the same way as the natural movement of the particulates (gases, vapours, dust) released. For heavier particles than air, evacuation will take place in the lower part of the room, for lighter particles at the top.
- the actual choice of the types of air inlet and outlet pipes is made considering the type of building (civil, industrial), the aesthetics of the room, the location of the machinery and the machinery. Depending on the amount of air flow calculated, the size of the room (length, width and especially height), type of air jet (isotherm, hot / cold non-isotherm), a number of air ducts of a certain type are chosen; or of two constructive types. Based on the chosen constructive type and the geometric dimensions (the distance between two adjacent holes, the height of the mouth from the floor), the kinematic (jet air velocity at the work area / stay, the air velocity in the plane of the discharge mouth) / cold, temperature difference between room air and jet) and jet type (with the influence of the ceiling, without the influence of the ceiling), based on the diagrams or calculation programs of the manufacturing companies, determine the size of the discharge opening type. The choice of drain holes is simpler because the suction speed damping is inversely proportional to the square of the speed and the influence of the movement in the suction plane is no longer felt at distances greater than  $2D_e$ . ( $D_e$  is the equivalent diameter of the suction mouth). The suction holes can have airflows, as a rule, up to  $2000 \text{ m}^3$ . Their dimensioning is also based on the room noise level. For social-cultural buildings, the air velocity in the plane of the suction mouth is  $v = 2-3 \text{ m/s}$ . For industrial buildings, usually the speed is  $v = 3-5 \text{ m/s}$ .

The local suction installations with the air velocity generate a limitation of the spread of the hazards, while at the same time ensuring the minimum openings necessary for the development of the technological processes. The devices used must ensure that the release is as complete as possible, do not obstruct the production process and allow the worker to be in a normal position so as not to be between the source of the harmfulness and the aspiration opening. These installations are made up of the capture device, air duct and fan. Devices for the capture of harmful substances in the immediate vicinity of the harmful outbursts may be: open, semi-closed or closed.

Fume cupboards are local aspiration devices located above, sideways or under sources. (Niculescu, N., et al., 1982). *Figure 2* shows the main types of hoods.

- The classic fume cupboard (*Figure 2a*) depending on the source of the source of the hazards, can be made with a square, circular or rectangular suction section. Its edges must exceed the perimeter source with  $(0,3 \div 0,4) y$ , where  $y$  represents the distance from the source. In order to smooth out the speed in the suction section, the opening angle of the cupboard  $\alpha \leq 60^\circ$  and at the bottom a levelling band with the width  $(0,1 \div 0,2) y$  can be mounted at the bottom;
- The fume cupboard placed near the wall or above the furnace door (*Figure 2b*) limits the draft air suction and is not influenced by the direction of air movement in the enclosure;
- The compartment fume cupboard (*Figure 2c*) is used for sources of long-range hazards, each compartment being provided with individual evacuation;
- The central and peripheral suction fume cupboard (*Figure 2d, e*) is used for working benches with different sizes and the surface of the source is variable;
- Folding fume cupboard (*Figure 2f*) allows to change the distance from the source and manipulate the parts and materials with transport devices (tread beams) by rotating the capture device  $90^\circ$ ;
- The telescopic fume cupboard (*Figure 2g*) allows, depending on the required technological operations, a change in the distance from the suction plane;
- Accumulator fume cupboard (*Figure 2h*) used for accidental leakage of high-rate hazards, allowing for momentary capture and evacuation.

The air captured at the workplace must be evacuated to the outside and, if necessary, cleaned according to the regulations in force. The drainage is done using the tubing. Methods for calculating the duct and the ventilator are based on the determination of the air flow resistance in the ducts and the definition of the ventilator operating conditions (flow, pressure, etc.). In general, piping dimensioning results as a compromise between economic restrictions (investment, operation - operation), standardized diameters, load losses, minimum transport speeds, the presence of corrosive pollutants, etc. The air velocity in the piping should be chosen for each installation, depending on the nature and properties of the pollutants. Transport speed is an essential factor for dust-containing exhaust systems, it must be above a minimum level to avoid dusting and time-blocking of the piping. It is even greater as the mass of particles is higher.



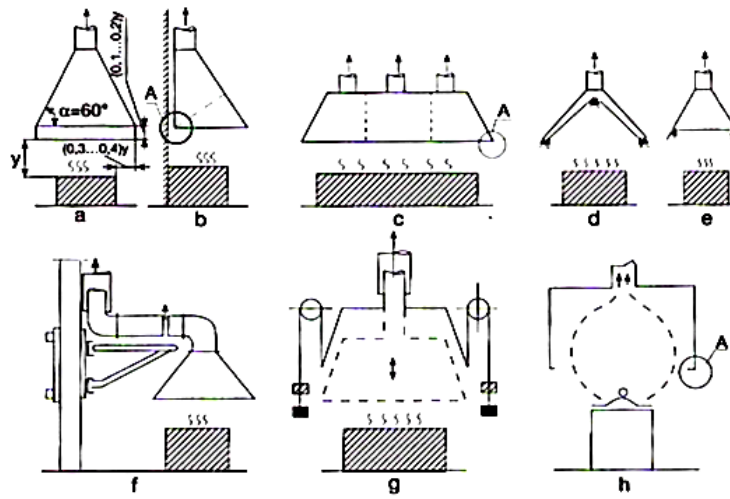


Fig. 2. Types of hoods

#### 4. Conclusions

1. Industrial ventilation systems aim to ensure the conditions of air purity and microclimate corresponding to human activity and the nature of the technological process. The fulfilment of these requirements contributes to the maintenance of the work capacity, the elimination of the professional illnesses, the increase of labour productivity, the quality of the products, etc.
2. When designing the local suction devices, the following factors shall be considered in order to determine their type, shape and dimensions: the shape and location of the machinery; nature and manner of deployment of technological processes; nature, quantity and mode of generation of harmful substances; the dimensions and constructional shape of the production rooms.
3. The main sizes involved in defining ventilation and air conditioning systems are: air pressure, air speed, temperature and humidity.

#### Acknowledgements

This paper was developed within the Nucleu-Programme, carried out with the support of MCI, project no.PN 18170202

#### References

- A., Cristea, *Air ventilation and conditioning*, Technical Publishing House, Bucharest, (1971).
- Doru, C., et al., *Guide for dimensioning industrial ventilation installations*, INSEMEX Publishing House, (2013).
- O., Bancea, *Industrial ventilation systems*, Editura Politehnică, Timimișoara, (2009).
- Matei, I., et al., *Environment engineering and underground ventilation*, Technical Publishing House, Bucharest, (2000).
- Niculescu, N., et al., *Ventilation and air-conditioning installations*, E.D.P., Bucharest, (1982).
- Rădoi, F., et al., *Methods and tools for determining air-flow in industrial ventilation installations*, UNIVERSITARIA SIMPRO 2016, Petroșani, ISSN-L 1842 – 4449, ISSN 2344 – 4754, (2016).

## Analysis of the behavior of metallic structures of multi-level buildings when exposed to dynamic effects due to explosive detonation

Kovacs Attila<sup>a\*</sup>, Ghicioi Emilian<sup>a</sup>, Laszlo Robert<sup>a</sup>, Dinu Florea<sup>b</sup>, Jitea Ciprian Ilie<sup>a</sup>

<sup>a</sup>National Institute for Research and Development in Mine Safety and Protection to Explosion – INSEMEX, 32-34 G-ral Vasile Milea street, Petroșani, 332047, Romania

<sup>b</sup>Departamentul of Steel Structures and Structural Mechanics, Politehnica University Timișoara, România

---

### Abstract

Explosions produced in urban areas are less likely to occur, but when they occur, they may pose a particular risk to buildings and occupants. When the charge is detonated in the immediate vicinity of major structural elements, major local failures can occur, which in turn can expand and generate generalized collapse (also called progressive collapse). Progressive collapse, which in many cases causes more casualties than the shock wave or the fragmentation effect (explosive charge or detachment from building elements), can be prevented by various measures that aim at reducing exposure, for example by increasing the distance security and vulnerability reduction by using systems with high redundancy and continuity between elements. The ability of a structure to withstand extreme actions without being affected at a disproportionately high level with the causal action is called robustness and is also required by the design rules in force (eg EN 1991-1-7, 2006). Awareness of these risks requires appropriate measures in the design and execution of building strength structures. Explosion calculation is, however, a difficult task (compared to other types of calculation), both in terms of evaluating the action (eg the maximum value of the resulting pressure or its variation on an element or structure) and the effects on the material or element, for example the effect of load speed on mechanical properties of steel or explosion-structure interaction.

**Keywords:** metal structures, explosive effect, measurements;

---

### 1. Introduction

Blasting charger can affect any type of structures depending the used. Explosives by the positioning of the charge and the type of the charge and specific structural characteristics of the targeted building. Over their lifespan, the buildings may be subjected to a variety of actions. Design and execution of buildings should take into account that some of these actions may reach extreme values, much higher than those currently used at initial design. Therefore, the buildings must be able to resist such events without being damaged disproportionately compared to the original cause. In such situations, the structure can be severely damaged, leading to partial or complete failure, e.g. the Ronan Point building, in London, in 1968. Explosions caused by gas accumulations have great significance, given the large number of residential buildings (and other types of spaces) where it is currently used. Hazards can be caused both by external distribution networks and the devices that use the gas inside. For example, in the United States, the average probability of producing a gas explosion is about  $1.8 \times 10^{-5}$  / year (NISTIR 7396, 2007). Studies conducted in the UK showed similar values of the order  $2.3 \times 10^{-5}$  / year to  $1.86 \times 10^{-5}$  / year. In other countries, e.g. Romania, there are no public data about such events, and this makes it difficult to assess the risk of such events based on the number of dwellings. The second important issue is the maximum pressure in the rooms affected by the explosion. Studies conducted after the accident in the Ronan Point building showed that these pressures rarely exceed the value of 17 kPa. Even if this value is much higher than "ordinary" loads, it is less than the amount recommended in EN 1991-1-7 (Mainstone RJ, 1974), namely 34 kPa. The pressure resulting from gas explosions is therefore very high compared to permanent or live loads (occupancy, wind, snow), which rarely exceed 4-5 kPa. The presence of voids limits first pulse intensity and pressure fluctuations of the second phase presents a reduced significance for the structural response. Unlike internal gas explosions, external explosions are usually produced from intentional causes, the source being both classic explosives (TNT, C-4, Semtex) but also improvised charges, like those based on ammonium nitrates, a chemical fertilizer widely

---

\*Kovacs Attila. Tel:+4-072-430-9726; fax: +40-254-545-277.  
E-mail address: attila.kovacs@insemex.ro.

used in agriculture. Because of the intentional nature, these events cannot be modelled using a Poisson distribution model, which is widely used to model the random occurrence of rare events (NISTIR 7396, 2007). Explosions caused by explosives, known as detonations, create shock waves that propagate at high speeds from the point of detonation. In terms of the effects on the structure, distance between the source of the explosion and structure plays a very important role. When the explosive charge is placed at greater distance from the structure, failure usually occurs due to excessive bending. The pressure released by the shock wave can be considered as uniformly distributed on the surface of the element. An explosion at a very short distance from the building causes a localized failure, like punching or shear failure. This is caused by the rigidity of the structural element, which produces inertial resistance to blast. Punching or shear-type failure occurs before structural element is able to respond by bending. The study presented in the paper investigated the response of beam-column steel elements subjected to close-in blasts. The research focused on the evaluation of typical steel frames response when subjected to direct effects of a blast and the direct calculation of blast loads for further numerical simulations. Two 3D frame specimens were tested inside a bunker using different charge weights, located at different distances. A numerical model was also validated using the advanced nonlinear dynamic analysis software Extreme Loading for Structures (US Departments of the Army, Navy and Airforce, 1990). The study is part of a research program devoted to the design of structures to sustain extreme loading events without collapse (Karlous V, Solomos G., 2013).

## 2. Blasting design and blasting scenarios

### 2.1 Description of specimens

Two 3D specimens were designed and constructed for testing under blast effects inside a bunker. Specimens were extracted from a typical moment resisting steel frame structure, see high-lighted areas in Fig.1.a. Due to space limitation in the bunker, the specimens were scaled down from 8.0 m span to 3.0 m span. First specimen (see Fig.1.a, Fig. 2.a) includes a column (blast induces deformations in the major axis direction), two half-span longitudinal beams rigidly connected to the flanges of the column using extended end plate bolted connections and one half-span transversal beam, connected to the column web using a simple clip angle connection.

The specimens were placed in a reinforced steel-country bunker fixed in every fire connection possibility.

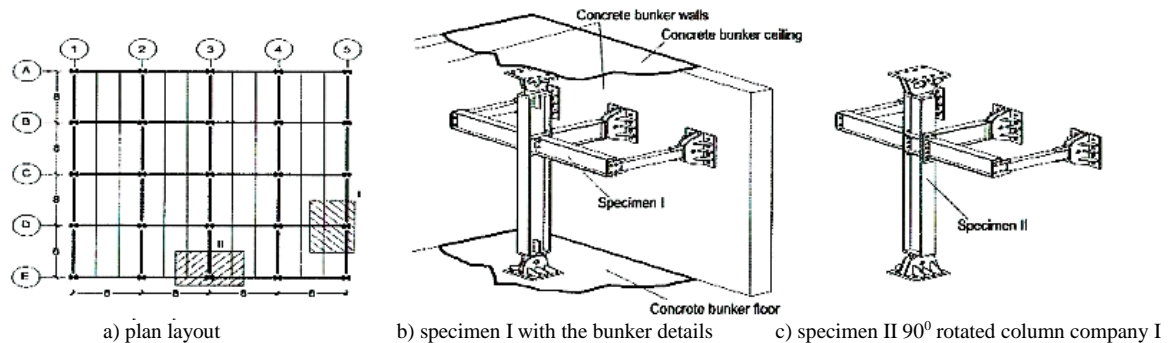
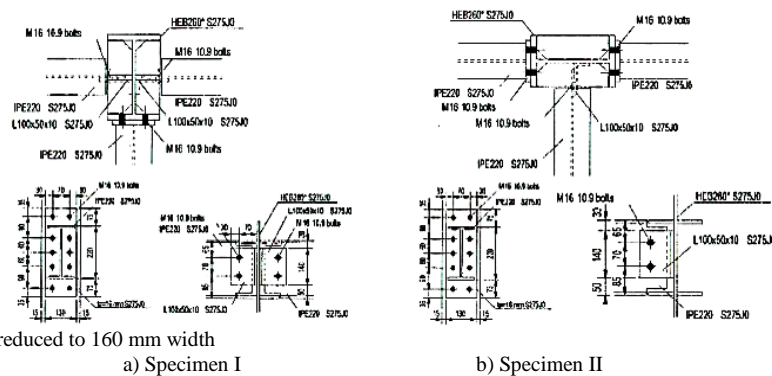


Fig. 1. Plan layout of the reference multi-story building with the position of the specimens extracted for testing and 3D views of specimens



\* flange of HEB260 column reduced to 160 mm width

Fig. 2. Details of the specimen's designs

Second specimen (see Fig. 1.b, Fig. 2.b) includes a column (blast induces deformations in the minor axis direction), two half-span longitudinal beams connected to the column web using simple clip angle connections and one half-span transversal beam, connected to the column flange using extended end plate bolted connections. For both specimens, lateral restraints made from tubular profiles were used at the ends of longitudinal beams.

Steel material in plates and profiles was S275J0 and bolts were grade 10.9. Table 1 summarizes the measured material properties of the specimens.

Table 1: Average characteristic values for materials in steel profiles, plates and bolts

Element	$f_y$ (N/mm <sup>2</sup> )	$A_{gt}$ (%)
	yield strength	Total elongation at maximum stress
Beam flange IPE220, $t = 9.2$ mm	345	28.0
Beam web IPE220, $t = 5.9$ mm	353	30.4
Column web HEB 260, $t = 10$ mm	407	27.0
Column flange HEB 260, $t = 17.5$ mm	420	27.0
End plate, $t = 16$ mm	305	17.1
Bolt, M16 class 10.9	965*	12.0

Note: \* 0.2% offset yield point

## 2.2. Blast effects

The main hazard components of an explosion are blast (overpressure), fragmentation, and thermal effect. In our study, only first issue has been of interest. As seen in Fig. 1.b, the peak pressure value depends very much on the distance of the detonation point from the structure of interest. Thus, the peak pressure value, and also the velocity of the blast wave, decrease rapidly by increasing the distance between the blast source and the target surface. The effect of distance on the blast characteristics can be taken into account by the introduction of scaling laws (Hopkinson B., 1915). These laws have the ability to scale parameters, which were defined through experiments, in order to be used for varying values of distance and charge energy release (Richards AB, Moore AJ., 2005). The experimental results are, in this way, generalized to include cases that are different from the initial experimental setup. The most common blast scaling law is the one introduced by Hopkinson (Tagel-Din H, Meguro K, 2000) and Cranz (Kaneko H., 1997). According to Hopkinson-Cranz law, a dimensional scaled distance is introduced as described by Eq. (1):

$$Z = R/(W^{1/3}) \quad (1)$$

where:  $Z$  is the scaled distance, in  $\text{m/kg}^{1/3}$ ,  $R$  is the distance from the detonation source to the point of interest [m] and  $W$  is the weight of the explosive [kg TNT or equivalent TNT].

As the scaled distance reduces, the peak overpressure increases. For example, in case of Murrah Federal Building in Oklahoma City, which collapsed in 1995 as a result of a blast produced by a large truck bomb (1814 kg equivalent TNT), located at a distance  $R$  of 1.5 m, the scaled distance was  $Z = 0.12 \text{ m/kg}^{1/3}$ , which resulted in a very large peak overpressure, estimated at 20 000 kPa. The scaling law from Eq. (1) should be corrected when blast test is done inside a bunker. A more general expression to evaluate the peak pressure (or peak overpressure) and the variation with the distance (Eq. (2)), is the one proposed by Richards and Moore (Dinu F., Mărginean I. Sigauan A., Kovacs A., Ghiciei E., Vasilescu D, 2016):

$$P = Ax(R/W)^b \quad (2)$$

where:  $P$  is the peak overpressure (kPa),  $A$  is the site constant (evaluated experimentally),  $a$  is site exponent (evaluated experimentally, is always negative),  $b$  is the site exponent for the charge weight (evaluated experimentally),  $R$  is the distance from the detonation source to the point of interest [m] and  $W$  is the weight of the explosive [kg TNT or equivalent TNT]. Using experimental calibration tests, Eq. (2) can be used in case of bunker tests. In the study, calibration blast tests were performed first, in order to evaluate the site exponents  $A$ ,  $b$  and  $a$ . Then, the specimens were subjected to blast of increasing intensities, obtained by increasing the charge weight and/or reducing the distance from the blast to the specimen.

## 3. On-field experiments on specimens

Fig. 3 shows the first specimen tested in the bunker. In order to evaluate the site exponents  $A$ ,  $b$  and  $a$ , and then the pressure inside the bunker, two Kistler pressure sensors were mounted on a special frame, at 4-meter distance from the specimen, in front of the bunker venting. Explosive material used in the testing has a TNT equivalence of 1. To note that the effects of gravity loads on the columns and beams were not considered in the test.

First four blasts used charges  $m_{1,1} = 125$  g,  $m_{1,2} = 250$  g,  $m_{1,3} = 500$  g and  $m_{1,4} = 1000$  g, located at 0.27 m from the beams mid-length, freely suspended (see Fig. 3). Last blast used a charge weight  $m_{1,5} = 1000$ g, located at the external face of the column, at mid-height, see Fig.3. The pressure measured after each explosion were  $p_{1,max} = 20$  kPa,  $p_{2,max} = 40$  kPa,  $p_{3,max} = 80$  kPa and  $p_{4,max} = 175$  kPa. The peak pressure during last explosion attained the maximum value,  $p_{5,max} = 1400$  kPa.

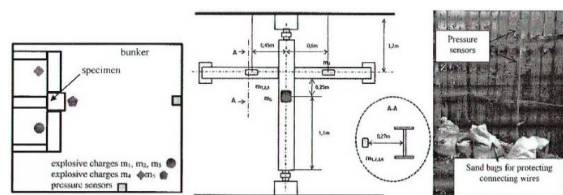


Fig. 3. Plan design and test set-up for specimen 1

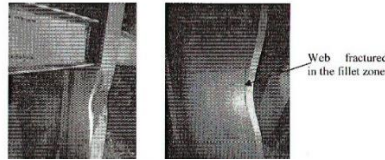


Fig. 4. Specimen 1 after blasting

While for first four explosions there were no visible deformations at the level of the specimen, the last charge, ms, caused severe local deformations of the column near the source, and the web complete fractured at the contact with the flange, in the fillet zone, for a length of 300 mm.

For calibration of experimental set-up, a charge with weight  $m = 125$  g was detonated at a distance  $d = 0.27$  m from the position of the pressure sensors. The value of the peak pressure was  $p_{calibration} = 1400$  kPa. With the values of the pressure measured during each detonation, the following specific coefficients of the bunker were determined:  $A = 3850$ ,  $a = -0.73$ ,  $b = 3.87/3 = 1.29$ . The peak pressure value of the blast wave, decrease rapidly with the distance between the blast source and the target surface, as seen in Fig. 5. Apart from the pressure measurements, also the permanent deflection of the specimen was measured in several points.

Second specimen was tested for three charges. First charge had a weight  $m_{1,2} = 500$  g, located at distance  $D_1 = 0.5$  m from the specimen and  $H = 1.0$  m height from the base of the column. No visible effects were recorded, nor in the beams or in the column. The test continued with detonation of a charge of  $m_{2,2} = 1815$  g, located at the same distance and height ( $D_2 = 0.5$  m,  $H = 1.0$  m). Web of the column has been deformed plastically out of plane for approximately 22 mm, but without any visible cracks (Fig. 6.a). The third detonation was produced by a charge blast of  $m_{2,3} = 1815$  g, located at same height but closer distance,  $D_3 = 0.20$  m. The web of the column has been completely removed within a length of almost 600 mm around the point of detonation, see Fig. 6.b.

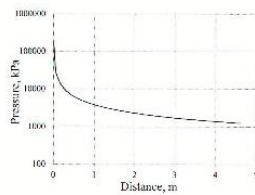


Fig. 5. Peak pressure vs. DISTANCE between the blast source and target surface

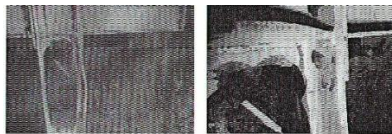
a) Damages consist in plastic deformations in column web after blast  $m_{2,2}$ b) complete failure of the web after blast  $m_{2,3}$ 

Fig. 6. Result of the free positioned charge after blasting

To note that, because the effects of gravity loads were not considered in the test, the column did not failed. However, in real conditions, the gravity loads are always present in the structure, and therefore such damage would be similar to a complete loss of bearing capacity (removal of the column). The permanent deflections of the specimen were measured in several points after the test and were used for numerical model validation.

#### 4. Results interpretation

The performance of the steel specimens undergoing close range detonations was also predicted using ELS (CODEC, 2012) (see Fig. 7). ELS utilizes a nonlinear solver based on the applied element method (Dinu F., Mărginean I. Sigauan A., Kovacs A., Ghicioi E., Vasilescu D, 2016) which is a derivative of the finite element method and the discrete element method. In ELS, the structure is modeled as an assembly of small elements, which are assumed to be connected by one normal and two shear springs located at contact points distributed around the element edges. The average normal strain is calculated by taking the average of the absolute values of strains on each face. When the average strain value at the element face reaches the separation strain, all springs at this face are removed and elements are not connected any



more (until they collide). Columns, beams, and plates were modeled as solid elements and could undergo deformations at the interface between the discretized elements. The constraints, made of tubular sections, were also modeled as solid elements. The bolts were modeled using individual springs: one for normal stresses and two for shear stresses. The column bases and transversal beam end connection to the bunker wall were considered pinned, and all displacements were prevented.

The shaded areas presented in Fig. 7 (left) indicate the surface of the elements loaded with the blast pressure.

Due to the dynamic, impulsive character of the blast load, strain rates effects in the material are very important. The rate dependency has been considered by means of the following relationships (Dinu F., Mărginean I. Sigauan A., Kovacs A., Ghicioi E., Vasilescu D, 2016):

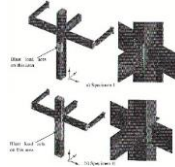


Fig. 7. Numerical models of specimens

Fig. 8 and Fig. 9 display the deformed shape of the specimens and the displacement history (along Y axis). Comparisons between numerical and experimental results show a very good agreement. The permanent deflection of the columns is very close to the measurements done after the test. Also, the extension of damage in the columns are very similar, with the same location and extension of fracture lines.

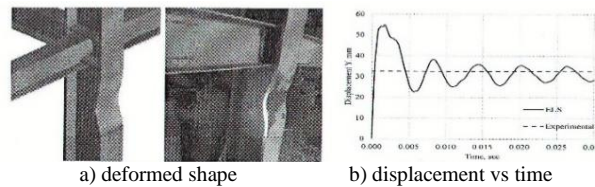


Fig. 8. Specimen I, comparison between free eyes examination and measurement

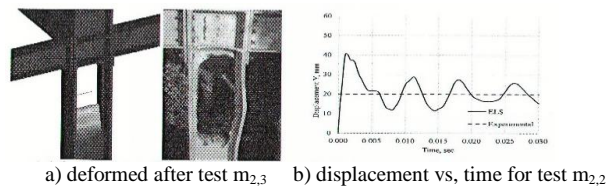
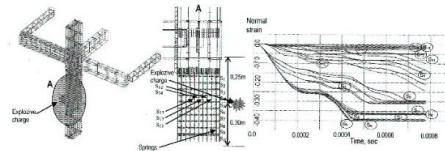
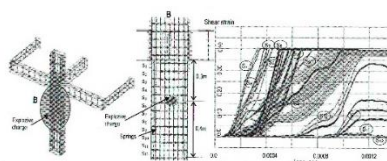


Fig.9. Specimen II, comparison between free eyes examination and measurement

The blast load pressure and therefore the blast effects decrease very rapidly with the distance from the explosive charge. For close-in detonations, the effects can concentrate in the area of the element adjacent to the explosive charge, while the effects on the remaining structure can be neglected. Thus, Fig. 10 .a and Fig. 10 .b show the shear strains in springs located in the fillet zone of the column web, within a length of 50 cm for specimen I and 60 cm for specimen II, respectively, measured from the bottom side of the beams. It can be seen that, even for small charges (maximum weight 1815g equivalent TNT), the local damages are extreme, but localized to the area close to the point of detonation.



a) specimen I behavior



b). specimen II behaviour

Fig. 10. Evolution of stain in the columns restarted

## 5. Conclusions

The study presented in the paper focused on the evaluation of close-in blast effects against steel frame structures. Two specimens were tested for charges of different weights and located at different distances to the specimens. The specimens were extracted from a six-story moment resisting frame structure, designed to meet the seismic design requirements for special moment frames. The variation of blast pressure with time and distance has been evaluated for bunker test conditions. The results showed that charges located at close distance can produce large damages in the members, with complete fracture of the section walls. Thus, for the specimen loaded against the strong axis (charge normal to the column flange), the blast caused severe local bending of the external flange, and fracture of the web at the contact with the flange, in the fillet zone. In case of specimen loaded against the weak axis (charge normal to of 600 mm, before structural element to be able to respond in bending. The later situation can be extremely dangerous, especially for buildings with perimeter steel moment resisting frames and interior gravity frames, if the loads cannot be distributed to the adjacent structural members. In the test, the complete failure of the column was prevented only due to the absence of any gravity loads. Numerical models that were calibrated using test data indicated a very good agreement, giving the possibility to extend the research to full scale structures, using different blast loading conditions. This project was continued in a larger scale on the basis of these results, mainly to expose a complex structure with much more elements (essentially using the same type of steel specimens). This structure was changed with extra weight to reproduce the real situation and to have information on the response of individual elements and the structure to blasting demolition.

## Acknowledgments

Funding for this research was provided by the Executive Agency for Higher Education, Research, Development and Innovation Funding, Romania, under grant PCCA 55/2012 "Structural conception and collapse control performance-based design of multistory structures under accidental actions" (2012-2016).

## References

- NISTIR 7396, *Best Practices for Reducing the Potential for Progressive Collapse in Buildings*, National Institute of Standards and Technology Administration, U.S. Dep. Of Commerce, (2007).
- Mainstone, R.J., *The hazards of Explosion, Impact and Other Random Loadings on Tall Buildings*, Current Paper 64/74, Building Resch. Establishment, Garston, UK, (1974).
- ELS, *Extreme loading for structures* (Version 3.1). Durham, NC: ASI, (2010).
- CODEC, "Structural conception and collapse control performance-based design of multistory structures under accidental actions" (2012-2016), Executive Agency for Higher Ed., Research, Development and Innovation Funding, Romania, PN II PCCA 55/2012, (2012).
- US Departments of the Army, Navy and Airforce, *Technical Manual, Army TM5-1300, Navy NAVFAC P-397, Air Force AFR 88-22, Structures to resist the effects of accidental explosions*. Washington, DC: US Dep. of Commerce, Nat. Techn. Inf. Service, (1990).
- Karlos V, Solomos G. "Calculation of Blast Loads for Application to Structural Components", JRC 32253-2011 with DG-HOME, Activity A5, Blast Simulation Technology Development, EU, Institute for the Protection and Security of the Citizen, (2013).
- Hopkinson, B. *British Ordnance Board Minutes 13565*, (1915).
- Richards, AB, Moore, AJ. *Blast vibration course measurement-assessment-control*, Terrock Pty Ltd, (2005).
- Tagel-Din, H, Meguro, K. "Applied element method for simulation of nonlinear materials: Theory and application for RC structures", *Structural Engineering/Earthquake Engineering*, International Journal of the Japan Society of Civil Engineers (JSCE), 17, 137-148, (2000).
- Kaneko, H. "Influence of strain-rate on yield ratio, Kobe Earthquake Damage to Steel Moment Connections and Suggested Improvement", JSSC Technical Report No. 39, (1997).
- Dinu, F., Mărginean, I. Sigauan, A., Kovacs, A., Ghicioi, E., Vasilescu, D., „*Effects of close range blasting on steel frames. Experiment testing and numerical validation*”, 2-16 *Proceedings of the International Colloquium on Stability and Ductility of Steel Structures SDSS – 2016*, Editor Dan Dubina and Viorel Ungureanu, ISBN (ECCS): 978-92-9147-133-1, pag. 699.

## Analysis of explosive environments that interacts with industrial ventilation systems

Matei Adrian<sup>a\*</sup>, Dragoescu Razvan<sup>a</sup>, Cioclea Doru<sup>a</sup>, Chiuzean Emeric<sup>a</sup>, Rădoi Florin<sup>a</sup>

<sup>a</sup>National Institute for Research and Development in Mine Safety and Protection to Explosion, INSEMEX, 32-34 G-ral Vasile Milea street, Petroșani, 332047, Romania

---

### Abstract

Anthropic activities involve the extraction of the transformation and use of natural resources.

During the process of extraction at the surface or underground of useful minerals, particles or gases resulting from the natural rock cracking or release from the rock mass appear in the working environment.

The process of transforming useful mineral substances is carried out on the surface in enclosed enclosures, involving the use of complex technological processes. During the course of these technological processes, explosive or toxic gases, dusts, mists, dusts or dusts may be released or may enter into the atmosphere.

To protect workers from underground mining works, the particles or gases produced during the extraction process are discharged into the atmosphere. Noxes of industrial nature in enclosed spaces are discharged into the atmosphere for similar reasons of worker safety.

In addition, other types of anthropogenic activities are being carried out to remove pollutants into the atmosphere. The first measure to ensure optimal microclimate conditions in enclosed spaces to protect workers is to provide good ventilation.

Pollutant substances found in the atmosphere can migrate over long distances reaching industrial dwellings or enclosures with fresh air introduced naturally or mechanically through ventilation systems. As a result of the exposure of short or long-term workers to toxic or explosive hazardous substances, workers may suffer from acute poisoning or occupational disease. When workers are surprised, the case of fires or explosions generated by flammable or explosive substances, the morbidity is extremely high.

This paper aims to analyze explosive environments interacting with industrial ventilation systems.

**Keywords:** environment, security, systems, ventilation;

---

### 1. Introduction

A discovery emerged in 1891 when Le Chatelier discovered the law to determine the limits of explosivity.

The lower explosive limit LIE (LEL) is the lowest concentration of gas or vapor in the air capable of generating the explosion in the presence of an efficient ignition source. This is considered to be the same with the lower limit of flammability LII (LFL). At a lower air concentration than LIE (LIE), the gas mixture is too weak to burn or produce the explosion even if the source of initiation is present.

The upper explosion limit LSE (UEL) is the highest concentration of gas or vapor in the air capable of generating the explosion in the presence of an efficient ignition source. This is considered to be similar to the upper limit of flammability LSI (UFL). At a higher air concentration than LSE (UEL), the gas mixture is too concentrated to burn or produce the explosion even if the source of initiation is present.

Le Chatelier's law was used by Coward and Jones in 1952 in his famous work on the explosive triangle.

In 1965 Zabetakis determines and publishes technical data on flammability limits, auto-ignition temperatures and combustion rate for 200 combustible gaseous substances.

In 1975, Hertzberg tried to establish in depth the theory of flammability but at an academic level, hard to use by practitioners. Later, this area was thoroughly deepened, and new laws emerging governing the phenomenon of flammability / explosiveness and factors influencing it.

---

\* Matei Adrian. Tel.: +40-254-541-621.  
E-mail address: adrian.matei@insemex.ro.



## 2. Flammability / Explosiveness of explosive substances

### 2.1. Le Chatelier Principle

Le Chatelier found that the lower and upper explosion limit of the air-methane mixture may change if other explosive gases are present. In this case, the lower LIE limit of explosive of the resulting mixture is calculated as follows: installed ventilation conditioning;

$$LIE = \frac{100}{\frac{C_1}{L_{i_1}} + \frac{C_2}{L_{i_2}} + \dots + \frac{C_n}{L_{i_n}}} \quad [\%] \quad (1)$$

where:

$C_1 \dots C_n$  - the percentage concentrations of each explosive gas in the mixture;

$L_{i_1} \dots L_{i_n}$  - the lower explosive limits of each explosive gas in the mixture.

The upper LSE explosion limit of the resulting mixture is calculated as follows:

$$LSE = \frac{100}{\frac{C_1}{L_{s_1}} + \frac{C_2}{L_{s_2}} + \dots + \frac{C_n}{L_{s_n}}} \quad [\%] \quad (2)$$

where:

$C_1 \dots C_n$  - the percentage concentrations of each explosive gas in the mixture;

$L_{s_1} \dots L_{s_n}$  - the upper explosive limits of each explosive gas in the mixture.

Lower and upper explosion limits define the explosive range within a straight segment comprised of 0% fuel gas and 100% air and 100% fuel gas and 0% air, fig. 1.



Fig. 1. Explosive range

### 2.2. Explosive chart Coward -Jones

In his work "Limits of flammability of gases and vapors" published in 1952 under the aegis of the Bureau of Mines, H. F. Coward and G. W. Jones, they first presented the form of explosive triangle. Coward-Jones's explosive triangle was a 2D representation of the explosive atmospheres consisting of simple methane and air.

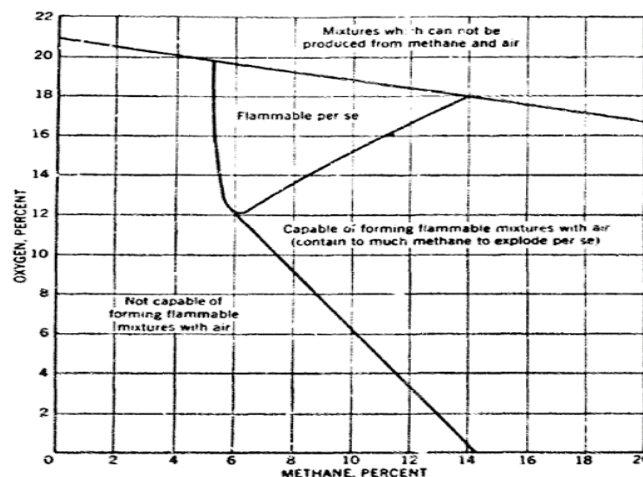


Fig. 2. Explosive Triangle - Coward - Jones

### 3. Analysis of factors influencing explosive environments

#### 3.1. Energy dependence

Le Chatelier and Boudouard note that in this phenomenon the combustion heat on the volume unit at the limit of the air to alkenes mixture is approximately a constant at the lower limit of flammability / explosivity. Burgess and Wheeler showed that the heat released by one mole of blend at the lower limit is almost constant for many fuel-to-air mixtures at normal temperature and pressure. So they came to the following addition:

$$x_L \cdot \Delta H_C = K \quad (3)$$

where :

$x_L$  is the percentage of combustion at the lower limit of the mixture,

$\Delta H_C$  is the combustion heat of the fuel which is approximately 10,5 kCal/mol,

$K$  is the constant that for Burgess and Wheeler has  $K = 1059$  for methane, Spakowski sets  $K = 1040$ , Hanley proposes  $K = 1120$  while Ramiro proposes  $K = 1042$ .

White and Zabetakis later proposed a correction as follows:

$$x_L \cdot \Delta H_C + \Delta H = K \quad (4)$$

where:

$\Delta H$  is the fraction of energy absorbed by ambient air.

#### 3.2. Temperature dependence

White has shown experimentally that the lower and upper limits are influenced by temperature. Rowley estimated temperature dependence as follows:

$$x_L \cdot \Delta H_C + \Delta H = 100 \cdot c_p \cdot T \quad (5)$$

where:

$c_p$  is the specific heat at constant air volume.

Later, the temperature difference was expressed relative to the relationship as follows:

$$\frac{x_L(T)}{x_L(T_0)} = 1 - \frac{c_{p,gaz-aer-amestec}}{x_L(T_0) \cdot (-\Delta H_C)} \cdot (T - T_0) \quad (6)$$

Zabetakis simplified the dependence on a constant one as follows:

$$\frac{x_L}{x_{L,0}} = 1 - \frac{0,75}{x_{L,0} \cdot \Delta H_C} \cdot (T - T_0) = 1 - 0,000721 \cdot (T - T_0) \quad (7)$$

Britton and Frurip have established linear temperature dependence as follow:

$$\frac{x_L(T)}{x_L(T_0)} = \frac{T_{AFT} - T}{T_{AFT} - T_0} = 1 - \frac{T - T_0}{T_{AFT} - T_0} \quad (8)$$

#### 3.3. Dependence on chemical composition

Jones was the first to note that at any specified temperature, the ratio at the lower limit, the amount required for the stoichiometric reaction, is approximately constant. He proposed a series of fuel cell constant.

Some values are shown in Table 1.

Table 1.

Nr. crt	Substance	Jones's constant
1	Methane	0,52
2	Ethane	0,57
3	Propane	0,59
4	Methyl Chloride	0,67
5	Ethyl Chloride	0,61
6	Propyl Chloride	0,61

Lloyd generalizes Jones' law by obtaining an expression of the form:

$$x_L = 0,55 \cdot x_{st} = 0,55 / (1 + 4,773 \cdot C_o)$$

$$x_U = 3,5 \cdot x_{st}$$

Zabetakis proposes a relationship based on the square root thus:

$$x_U = 6,5 \cdot \sqrt{x_L} + 4,8 \cdot \sqrt{x_{st}}$$

### 3.4. Dependence on the fuel substance

When more gases are involved, Le Chatelier's law is the only tool to make a prediction of the flammability of the mixture. Le Chatelier issued the following law: "If we have more gases each with explosive limit concentrations, then if we homogenize them we will get a mixture of combustible gases with the concentration limit at the explosive limit"

This law can be written as:

$$\frac{x_1}{x_{L,1}} + \frac{x_2}{x_{L,2}} = 1 \quad (9)$$

Mashuga identified the hypotheses resulting from Le Chatelier's law, and are further exposed:

1. the calorific capacities produced are constant;
2. the number of moles of gas is constant;
3. the pure gas combustion kinetics is independent and unchanged the presence of other combustible gases;
4. The increase of the adiabatic temperature to the limit of flammability is the same for all gases.

### 3.5. Pressure dependence

An increase in pressure has a low effect on the lower limit, although the upper limit can be enlarged; however, the magnitude of the reaction to the flame front is impaired. Based on experimental data on natural gas (85-95% methane and 15-5% ethane) by Jones, Zabetakis, suggested that the limits vary linearly with the initial pressure logarithm. This is

$$x_L = 4,9 - 0,71 \log P \text{ (atm)}$$

$$x_U = 14,1 - 20,4 \log P \text{ (atm)}$$

Fig. 3. shows the variation in flammability under overpressure conditions.

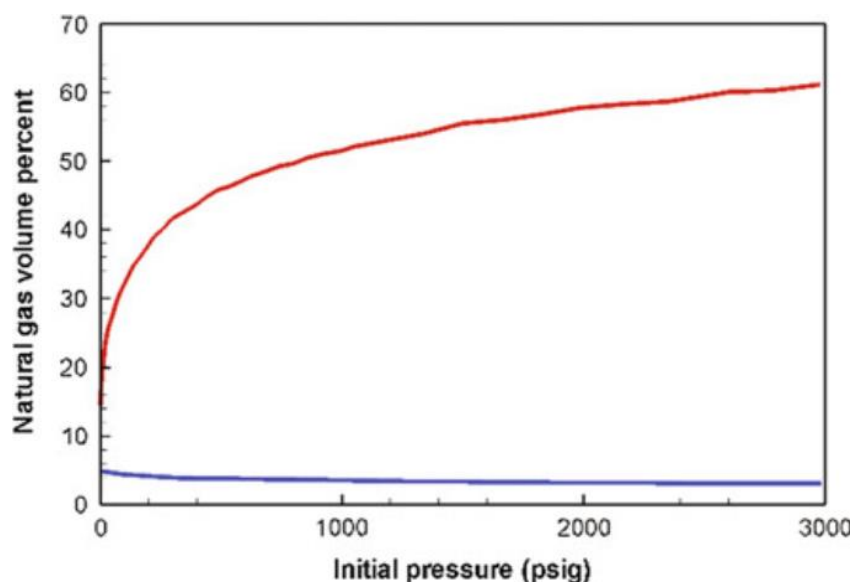


Fig.3. Flammability curve – overpressure

Fig. 4. shows the variation of flammability under low pressure conditions under atmospheric pressure after Lewis and Von Elbe.

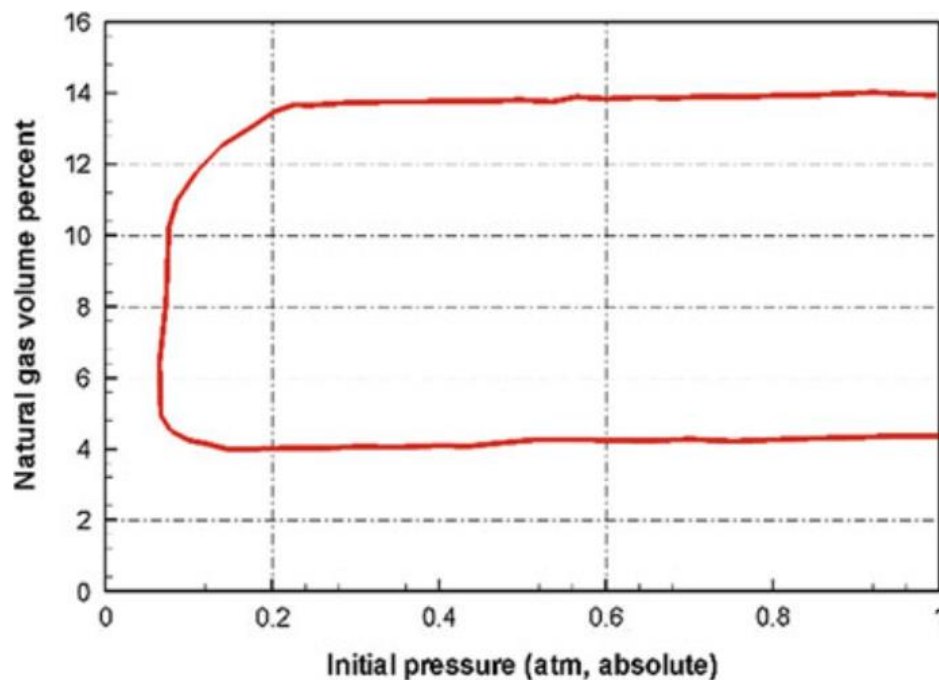


Fig. 4. Flammability curve - Lewis and Von Elbe

Currently, professional methods in the field of flammable atmospheres consisting of gas mixtures and dilution gases are given in ISO 10156/2010, which contains test methods and methods for determining the flammability of gas mixtures.

The calculation methods use the flammability limits and the  $T_{ci}$  coefficient for flammable gases and vapours.

$T_{ci}$  values are given for pressures under atmospheric pressure with air as an oxidant, also referred to as the maximum permitted MXC concentration.

In contrast, the coefficients of equivalence in nitrogen ( $K$ ) for gas mixtures are calculated with the relation:

$$K_{i,j} = \frac{MX \cdot C_{i,j} \left( \frac{100}{T_{ci}} - 1 \right)}{(100 - MX \cdot C_{i,j})} \quad (10)$$

Table 2 gives the coefficients in equivalent nitrogen.

Table 2.

Gaz	N <sub>2</sub>	CO <sub>2</sub>	He	Ar	Ne	Kr	Xe	SO <sub>2</sub>	SF <sub>6</sub>	CF <sub>4</sub>
$K_i$	1	1,5	0,5	0,5	0,5	0,5	0,5	1,5	1,5	1,5

Table 3 shows the  $T_{ci}$  values for common flammable gases.

Table 3.

Gaz	H <sub>2</sub>	CO	Metan	Etan	Butan	Etilena	Propan	Propena	Acetilena	n-Hexan
$T_{ci}$	5,7	20	8,7	7,6	5,7	6	6	6,5	4	3,5

#### 4. Conclusions

Explosion is the particular case of combustion at the level of explosive mixtures of combustible gases and / or combustible vapors and / or combustible dusts with air where the oxidation reactions occur rapidly and violently with heat, light, and light generation high pressures.

Technical data on the flammability / explosiveness of combustible substances, their properties, the main factors of influence are presented.

Lower and upper explosion limits define the range of explosive that is within a straight segment between 0% fuel gas and 100% air and 100% fuel gas and 0% air.

Factors influencing the explosive nature of combustible substances are generated by dependence on: energy, temperature, chemical composition, fuel substance and pressure.

## Acknowledgements

This paper was developed within the Nucleu-Programme, carried out with the support of Romanian Ministry of Research and Innovation, project no. PN 18 17 02 02, project title: Research on improving health and safety in hazardous environments with explosive, flammable and toxic atmospheres (in Romanian: Cercetări privind îmbunătățirea stării de securitate și sănătate în medii periculoase cu atmosfere explozive, inflamabile și toxice).

## References

- Băltărețu, F., Matei I. – *Ghid practic pentru proiectarea și verificarea instalațiilor de aeraj parțial*, Ministerul Minelor, Petrolului și Geologiei, (1987).
- Băbuș, G., Moraru, R., ș.a., *Ingineria mediului și ventilația în subteran*, Editura Tehnică București, (2000).
- Ianc, N., *Reducerea impactului produs asupra mediului de gazul metan din minele de cărbuni din Valea Jiului*, Teza de doctorat, Universitatea din Petroșani, (2015).
- Lupu, C., *Metanul din minele de cărbune*, Editura INSEMEX, Petroșani, (2007).
- Tomescu, C., *Cercetări privind creșterea gradului de securitate în procesul recuperării și valorificării metanului din arealul carbonifer al Văii Jiului*, Teza de doctorat, Universitatea din Petroșani, (2015).

## Efficiency of complex ventilation networks

Cioclea Doru<sup>a\*</sup>, Ianc Nicolae<sup>a</sup>, Morar Marius<sup>a</sup>, Matei Adrian<sup>a</sup>, Drăgoescu Răzvan<sup>a</sup>

<sup>a</sup>National Institute for Research and Development in Mine Safety and Protection to Explosion, INSEMEX, 32-34 G-ral Vasile Milea street, Petroșani, 332047, Romania

---

### Abstract

The first measure for ensuring optimal occupational health and safety conditions in underground minerals exploitation is the achievement of proper ventilation (Teodorescu C., et al, 1980). For ensuring proper ventilation of each mine working, there is imposed the optimization of air flow repartition in each branch of the network, fact which involves the mine's entire ventilation network solving (Hargreaves D.M., et al, 2007). In hard coal exploitation, opening, preparation and exploitation works undergo a nonlinear continuously and differentiated process of specific aerodynamic parameters degradation. Following the changes in time of aerodynamic parameters of mine workings, specific ventilation parameters also change, leading to the ventilation network's deviation from the aerodynamic point of view, compared to the standard situation (Patterson A. M., 1992). The ventilation network's deviation is directly proportional to costs required for air circulation and inversely proportional to the efficiency of the ventilation network's aeration. In order to assess the efficiency of ventilation networks (Băbuț, G.B., and Moraru, R.I., 2018), a new parameter has been introduced, namely the ventilation network's standard deviation. In this paper is presented the theoretical basis and the determination of the standard deviation applied for Lupeni mine unit ventilation network.

*Keywords:* efficiency, modelling, software, solving, ventilation, ventilation networks;

---

### 1. Lupeni Mine Unit Ventilation Network

Lupeni mine unit is equipped with two main ventilation stations: Shaft 1 East and Central Rising.

Underground mine workings are ventilated under the depression of the Main ventilation station Central Rising, fitted with two axial fans type VOKD 1.8.

Underground mine workings which are ventilated under the depression of the Main ventilation station Shaft 1 East is equipped with two axial fans type VOD 3.0.

Fresh air entrance in underground is performed through 5 mine workings: Stefan shaft, shaft no. 12, shaft with skip, coast gallery horizon 650 and auxiliary shaft south.

Central Rising and Shaft 1 East circuits are extended over 5 horizons: horizon 300, horizon 360, horizon 400, horizon 480, horizon 650.

### 2. Lupeni Mine Unit Ventilation Network Solving

For solving the ventilation network of Lupeni mine unit was used VENTSIM Visual Advanced software, designed and developed in Australia.

A number of 386 junctions and 481 branches have been inserted into the software's database. Figure 1 presents the 3D spatial ventilation network of Lupeni mine unit.

After the ventilation network's solving (Cioclea D, et al, 2012; Cioclea D, et al, 2014; Gherghe I., 2004), the following results have been obtained:

Air flow at the level of the longwall with undermined coal bed no. 1, seam 3, block II, sublevel II was 3.2 m<sup>3</sup>/s; Air flow at the level of the longwall with undermined coal bed no. 1, seam 3, block II, sublevel III was 3.2 m<sup>3</sup>/s; Air flow at the level of the longwall with undermined coal bed no. 11, seam 3, block V, was 4.0 m<sup>3</sup>/s; Air flow at the level of the

---

\* Cioclea Doru. Tel: +40 727 200 779; Fax: +40 254 546277.  
E-mail address: doru.cioclea@insemex.ro.

longwall no. 3, seam 3, block V, was 3.7 m<sup>3</sup>/s; Air flow at the level of the longwall no. 2C, seam 3, block V, was 6.6 m<sup>3</sup>/s; Air flow at mine level was 83.7 m<sup>3</sup>/s; Air flow at the level of the main ventilation stations was 85.4 m<sup>3</sup>/s.

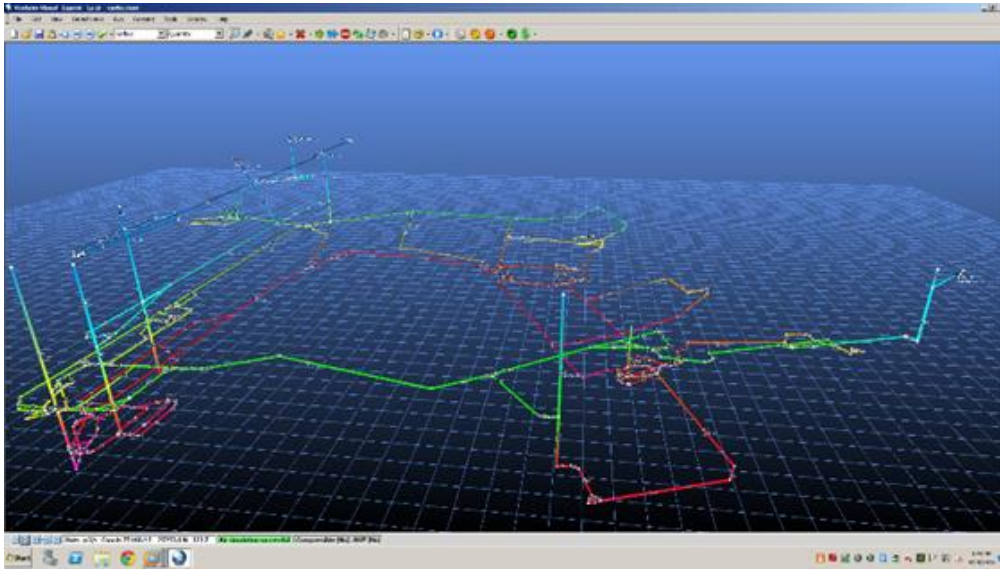


Fig. 1. Lupeni mine unit ventilation network in 3D system

### 3. Methods for Determining the Ventilation's Efficiency

For the classification of ventilation networks in terms of efficiency (Cheng J., et al, 2010; Cheng J., et al, 2011) are used several methods, namely: Equivalent orifice method, Ratios method, Temperament method.

#### 3.1. Equivalent Orifice Method

The equivalent orifice of a mine is a ventilation parameters using which there may be characterized the ventilation capacity and it represents a fictional orifice A, performed into a thin wall, through which at a pressure difference on the two sides of the wall equal with the mines depression “h”, will be circulated the same amount of air Q as the one circulated through the mine.

#### 3.2. Ratios Method

This method is characterized by the efficiency of the mine's general ventilation and takes into account the size of ratios:

$$\frac{Q_{sc}}{Q_{ef}} \text{ and } \frac{h_{ef}}{h_t} \quad (1)$$

in which:

$Q_{sc}$  - air flow short-circuited in underground, m<sup>3</sup>/s;  
 $Q_{ef}$  - air flow which ventilates the work fronts, m<sup>3</sup>/s;  
 $h_{ef}$  - depression of the mine, determined by measurements, N/m<sup>2</sup>;  
 $h_t$  - theoretical depression of the mine, determined by calculation, N/m<sup>2</sup>.

#### 3.3. Temperament Method

In order to classify the manner in which a mine working's ventilation is achieved is used the T temperament term. Temperament represents the easiness with which the fluid passes the mine working.

### 4. Standard Deviation

Underground hard coal exploitation involves the performance of a complex of opening, preparation and exploitation workings in order to extract and transport the useful minerals to the surface. Once with the increase of the mine workings usage, their aerodynamic parameters negatively change, having severe consequences from the point of view of air flowing on their alignment. The degradation in time of aerodynamic parameters of mine workings leads to the

change of the ventilation network's aerodynamic parameters. The change of aerodynamic parameters of mine workings in relation with the initial value represents the ventilation network's deviation (Cioclea D., 2015).

#### 4.1. Standard Deviation of a Ventilation Network

The standard deviation of a ventilation network is defined as the change in time of aerodynamic parameters specific for a ventilation network in relation with the aerodynamic parameters specific for the same ventilation network in standard conditions.

For determining a parameters which is applicable for any ventilation network, regardless of its' structure and complexity, there has been used the term of ventilation network in standard conditions.

The ventilation network in standard conditions represents the structure of a ventilation network evolving at a certain time, which is characterized by the fact that all active mine workings have associated the aerodynamic parameters specific for the moment of entrance into exploitation.

Aerodynamic parameters specific for the entrance into exploitation of a mine working and the ones established through the technical project. Aerodynamic parameters specific for a mine working at a certain time during exploitation air determined through flow and pressure measurements performed on site.

#### 4.2. Establishing the Standard Deviation of a Ventilation Network

For assessing the ventilations efficiency at a certain moment is used the  $A_s$  parameter which represents its' standard deviation. The standard deviation of a ventilation network is defined by the ratio between the equivalent orifice of the ventilation network at a certain moment  $A$  and the equivalent orifice of the ventilation network in standard conditions  $A_0$ :

$$A_s = \frac{A}{A_0} \cdot 100 \quad (2)$$

in which:

$A$  - equivalent orifice of the ventilation network at a certain moment ( $m^2$ );

$A_0$  - equivalent orifice of the ventilation network in standard conditions ( $m^2$ ).

Equivalent orifice of the ventilation network at a certain moment  $A$  is determined using the approximate Eq. 3:

$$A \cong \frac{1.2}{\sqrt{R}} \quad (m^2) \quad (3)$$

Equivalent orifice in normal conditions may be calculated using the exact Eq. 4 (i.e. for two ventilation stations):

$$A = 1.2 \sqrt{\frac{Q_m^3}{Q_{s1} h_{s1} + Q_{s2} h_{s2}}} \quad (m^2) \quad (4)$$

Equivalent orifice of the ventilation network in standard conditions  $A_0$  is determined using the approximate Eq. 5:

$$A_0 \cong \frac{1.2}{\sqrt{R_0}} \quad (m^2) \quad (5)$$

Equivalent orifice of the ventilation network in standard conditions (i.e. for two ventilation stations) may be also calculated using the exact Eq. 6:

$$A_0 = 1.2 \sqrt{\frac{Q_{0m}^3}{Q_{s01} h_{s01} + Q_{s02} h_{s02}}} \quad (m^2) \quad (6)$$

In these conditions, the standard deviation of the ventilation network  $A_s$  is:

$$A_s = \sqrt{\frac{R_0}{R}} \cdot 100 \quad ; \quad A_s = \sqrt{\frac{Q_m^3 (Q_{s01} h_{s01} + Q_{s02} h_{s02})}{Q_{0m}^3 (Q_{s1} h_{s1} + Q_{s2} h_{s2})}} \times 100 \quad (7)$$

#### 4.3. Characterization of Ventilation Networks Depending on the Standard Deviation

The standard deviation of a ventilation network is a non-dimensional parameter which establishes the level of deviation from standard conditions.

In order to characterize ventilation networks in relation with the standard deviation is required the establishment of periods defining concrete states specific for the ventilation network.



Therefore, ventilation network may be split into three categories:

- Ventilation network with optimal standard deviation characterized by  $A_s > \frac{2}{A_0} \cdot 100$
- Ventilation network with acceptable standard deviation characterized by  $A_s = \frac{1}{A_0} \cdot 100 \div \frac{2}{A_0} \cdot 100$
- Ventilation network with unacceptable standard deviation characterized by  $A_s = 0 \div \frac{1}{A_0} \cdot 100$

If the ventilation network is assessed from the standard deviation point of view in different categories, then is chosen the assessment which takes into account the exactly calculated equivalent orifice.

## 5. Lupeni Ventilation Network Solving in Standard Conditions

For solving Lupeni ventilation network in standard conditions was used the database of VENTSIM Visual Advanced (User Guide, 2014) for solving the ventilation network in normal conditions. Figure 2 presents the 3D ventilation network of Lupeni mine unit solved for standard conditions.

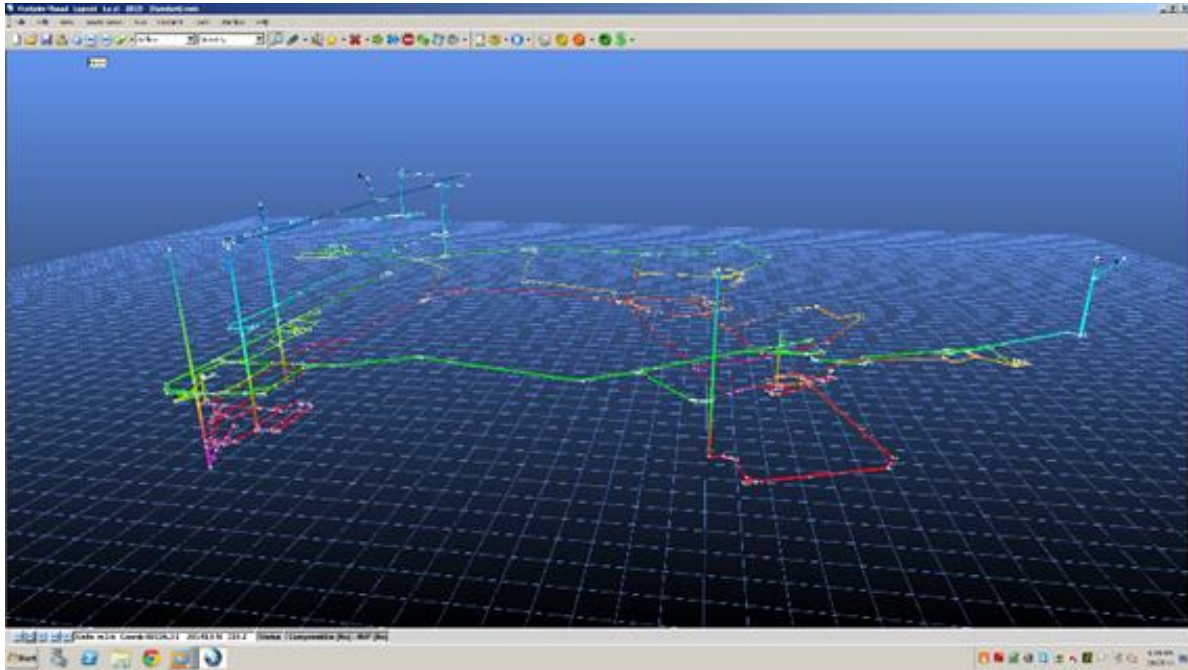


Fig. 2. 3D standard ventilation network of Lupeni mine unit

After the ventilation network's solving for standard conditions, the following results have been obtained:

Air flow at the level of the longwall with undermined coal bed no. 1, seam 3, block II, sublevel II was 3.4 m<sup>3</sup>/s; Air flow at the level of the longwall with undermined coal bed no. 1, seam 3, block II, sublevel III was 2.8 m<sup>3</sup>/s; Air flow at the level of the longwall with undermined coal bed no. 11, seam 3, block V, was 8.0 m<sup>3</sup>/s; Air flow at the level of the longwall no. 3, seam 3, block V, was 8.6 m<sup>3</sup>/s; Air flow at the level of the longwall no. 2C, seam 3, block V, was 15.3 m<sup>3</sup>/s; Air flow at mine level was 107.6 m<sup>3</sup>/s; Air flow at the level of the main ventilation stations was 108.6 m<sup>3</sup>/s.

## 6. Determining the Standard Deviation for Lupeni Mine Unit Ventilation Network

For determining the standard deviation of a mine is required the knowledge of aerodynamic parameters specific for the ventilation network, respectively of operational parameters of active fans. The aerodynamic and operational parameters are required both for the ventilation network solved in normal conditions, as well as for the ventilation network brought to its' standard condition.

### 6.1. Standard Deviation Calculation

For calculating the standard deviation is determined the equivalent resistance of the ventilation network in normal conditions:

$$R = \frac{R_1 \cdot R_2}{(R_1 + R_2 + 2 \sqrt{R_1 \cdot R_2})} \text{ (Ns}^2\text{/m}^8\text{)} \quad (8)$$

Particularly for Lupeni mine unit ventilation network we have the following:  $R = 0.26753 \text{ (Ns}^2/\text{m}^8\text{)}$

The equivalent resistance of the ventilation network in standard conditions is calculated using Eq. 9:

$$R_0 = \frac{R_{01} R_{02}}{(R_{01} + R_{02} + 2 \sqrt{R_{01} R_{02}})} \text{ (Ns}^2/\text{m}^8\text{)} \quad (9)$$

Particularly for Lupeni mine unit ventilation network we have the following:  $R_0 = 0.05846 \text{ (Ns}^2/\text{m}^8\text{)}$ .

Based on previous results is determined the ventilation network's equivalent orifice in normal conditions:

$$A \cong \frac{1.2}{\sqrt{R}} \text{ (m}^2\text{)}; A \cong 2.32004 \text{ (m}^2\text{)} \quad (10)$$

The equivalent orifice in normal conditions is exactly calculated using Eq. 11:

$$A = 1.2 \sqrt{\frac{Q_m^3}{Q_{s1} h_{s1} + Q_{s2} h_{s2}}} \text{ (m}^2\text{)} ; A = 1.93973 \text{ (m}^2\text{)} \quad (11)$$

The equivalent orifice of the ventilation network in standard conditions is calculated using the approximate Eq. 12:

$$A_0 \cong \frac{1.2}{\sqrt{R_0}} \text{ (m}^2\text{)}; A_0 \cong 4.96308 \text{ (m}^2\text{)} \quad (12)$$

The equivalent orifice in standard conditions is exactly calculated using Eq. 13:

$$A_0 = 1.2 \sqrt{\frac{Q_{0m}^3}{Q_{s01} h_{s01} + Q_{s02} h_{s02}}} \text{ (m}^2\text{)}; A_0 = 3.78194 \text{ (m}^2\text{)} \quad (13)$$

Based on the previous results is determined the ventilation network's standard deviation:

Thus, there may be determined the standard deviation based on the approximate mathematical Eq. 14:

$$A_s \cong \sqrt{\frac{R_0}{R}} \cdot 100; A_s \cong 46.75 \quad (14)$$

Also, by using Eq. 15 which uses the values of exactly calculated equivalent orifices for the situation of normal and standard conditions ventilation networks.

$$A_s = \frac{A}{A_0} \cdot 100 \text{ or } A_s = 51.29 \quad (15)$$

## 6.2. Ventilation Network Characterization in Relation with the Standard Deviation

In order to characterize the ventilation network in relation with the standard deviation, there are firstly calculated the ratios  $\frac{1}{A_0} \times 100$  and  $\frac{2}{A_0} \times 100$ , using the equivalent orifice in standard conditions with approximate value:

$$\frac{1}{A_0} \times 100 = 20.149; \frac{2}{A_0} \times 100 = 40.297 \quad (16)$$

or by using the equivalent orifice in standard conditions with exact value:

$$\frac{1}{A_0} \times 100 = 26.44; \frac{2}{A_0} \times 100 = 52.883 \quad (17)$$

For the value of the standard deviation  $A_s = 46.75$ , calculated using the value of the approximate equivalent orifice, results that Lupeni mine unit ventilation network frames into category a) "Ventilation network with optimal standard deviation".

Also, for values of the standard deviation  $A_s = 51.29$ , calculated using the value of the exact equivalent orifice, results that Lupeni mine unit ventilation network frames at the upper limit of category b) "Ventilation network with acceptable standard deviation".

If the ventilation network is assessed in terms of standard deviation into different categories, then is chosen the ventilation network assessment which takes into account the exactly calculated equivalent orifice.

Therefore, the final assessment of Lupeni mine unit ventilation network in terms of standard deviation is: The ventilation network frames into category b) "Ventilation network with acceptable standard deviation".

## 7. Conclusions

In order to assess the efficiency of the ventilation network was inserted the  $A_s$  parameter, representing its' standard deviation.

Results obtained after solving Lupeni mine unit ventilation network in normal exploitation and in standard conditions highlight the fact that a total flow of 85.4 m<sup>3</sup>/s respectively 108.6 m<sup>3</sup>/s is circulated in the ventilation network, through the two main ventilation stations: Central Rising and Shaft 1 East.

The assessment of Lupeni mine unit ventilation network in terms of standard deviation highlights the fact that the ventilation network frames into category b) "Ventilation network with acceptable standard deviation".

## Acknowledgements

This paper was developed within the Nucleu-Programme, carried out with the support of MCI, project no.PN 18170202

## References

- Băbuș, G.B., Moraru, R.I., *Occupational risk assessment: imperatives for process improvement*, Quality - Access to Success, Volume 19, Issue 166, pp. 133-144, (2018).
- Cheng, J., Yang, S., Lou Y., *Mathematical models for optimizing and evaluating mine ventilation system*, Proceedings of the 13th United States/North American Mine Ventilation Symposium, Hardcastle S., McKinnon D., (Eds.), Laurentian University, Sudbury, 278-285, (2010).
- Cheng, J., Yang, S., *Data mining applications in evaluating mine ventilation system*, Safety Science, 50, 918-922, (2012).
- Cioclea, D., Lupu, C., Toth, I., Gherghe, I., Boantă, C., Rădoi, F., *Fast network connections for ensuring decision operativity in mining ventilation*, Environmental Engineering and Management Journal, 11, 1225-1228, (2012).
- Cioclea, D., Toth, I., Gherghe, I., Tomescu, C., Șuvar, M.C., Păsculescu, V.M., *Analysis of transitory phenomena generated by underground explosions upon the ventilation networks*, Environmental Engineering and Management Journal, 13, 1401-1407, (2014).
- Cioclea, D., *Methodology for establishing the standard deviation at the level of a complex ventilation network*, (in Romanian), Nucleu project, INSEMEX Research Study, Petroșani, (2015).
- Gherghe, I., *Rationalization of Jiu Valley hard coal mines ventilation networks in terms of their restructuring, following the closure of inactive areas*, (in Romanian), INSEMEX Research Study, Petroșani, (2004).
- Hargreaves, D.M., Lowndes, I.S., *The computational modelling of the ventilation flows within a rapid development drive*, Tunnelling and Underground Space Technology, 22(2):150-160, (2007).
- Patterson, A. M., *The Mine Ventilation Practitioner's Data Book*, M.V.S. of South Africa, (1992).
- Teodorescu, C., Gontean, Z., Neag, I., *Mining Ventilation*, (in Romanian), Technical Publishing House Bucharest, Romania User Guide, (2014), Ventsim Visual Advanced, (1980).
- Wei, G., *Optimization of mine ventilation system based on bionics algorithm*, Procedia Engineering, 26, 1614-1619, (2011).

## Increasing the safety, quality and efficiency of demolition/dismantling of metal structures by using blasting works

Laszlo Robert<sup>a\*</sup>, Gheorghiosu Edward<sup>a</sup>, Vasilescu Dragos Gabriel<sup>a</sup>, Kovacs Attila<sup>a</sup>,  
Jitea Ciprian<sup>a</sup>, Galvitu Mihaela<sup>b</sup>

<sup>a</sup>National Institute for Research and Development in Mine Safety and Protection to Explosion, INSEMEX, 32-34 G-ral Vasile Milea street, Petroșani, 332047, Romania

<sup>b</sup>MSVM Proiect SRL, Otelarilor Street, 331008 Hunedoara, Romania

---

### Abstract

This article describes the practical way of realizing the demolition of metallic structures using the computer modelling of the works for the preparation of structures according to the chosen demolition concept, so that the blasting works and demolition are executed under conditions of efficiency, quality and security.

**Keywords:** demolition by blasting works, metal structures, explosive shaped charges, computer simulation;

---

### 1. Introduction

The restructuring of the steel industry in Romania has led to the closure of many productive units, the main reason being the high production costs and the high level of pollution. In recent years, with the reduction or stopping of the primary production flow - of which belong the agglomeration sections as well as Siemens - Martin furnaces, an ample process of greening these industrial platforms has begun.

For this purpose, many demolition activities were carried out, part of which was done by blasting works. From a technical point of view, the most interesting demolition works are those of metal structure, such as furnaces. Because of the complexity of these structures, a mechanical demolition would have been difficult, which is why demolition was done by blasting.

In most cases, the demolition of metal constructions by blasting works involves more problems compared to the situation of demolition of classical constructions. This is due to the complicated equilibrium systems of these structures, to the safety measures to be taken, to the particularities of the type explosive and initiating materials used as well as their location.

The article describes the practical way of realizing the demolition of a Siemens - Martin furnace, using the computer modelling of the works for the preparation of structures according to the chosen demolition concept, so that the blasting works and demolition are executed under conditions of efficiency, quality and security.

### 2. Furnance assembly description

The iron casting furnaces (Fig. 1) have a weight of up to 2 000 tons and consist mainly of a furnace body, a cleaning bag and a flanged pipe.

(1). The actual body of the furnace consists of the inner brick work made of refractory brick, followed by the cooling elements and the outer steel sheet armour.

Support pillars of the access platforms and the loading device, of 4 to 7 pieces, are arranged equidistant around the furnace body. The pillars are quenched, made of 30 to 40 mm thick steel. Bridges between these pillars are developed to access the main furnace installations. The number and height of the pillars, respectively the number and height of the platforms, differ according to the volume and year of the furnace construction.

---

\* Laszlo Robert. Tel.: +40 722 305 573; fax: +40 254 546 277  
E-mail address: robert.laszlo@insemex.ro

(2). The cleaning bag is a metallic cylindrical construction that rests on the bottom on a resistance structure made of 4 to 8 reinforced concrete pillars.

(3). The flanged pipe is supported at the bottom on the cleaning bag and at the top of the furnace body, connecting them. It is made of rolled sheet, having a masonry of refractory brick inside.

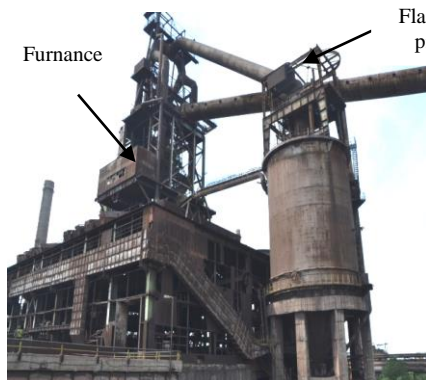


Fig. 1. Furnace, flanged pipe and cleaning bag assembly



Fig. 2. Furnace assembly after preparation for blast

### 3. Furnance blast demolition

#### 3.1. Considerations on demolition by blasting

The successful completion of many demolition works by blasting various metal constructions led to the conclusion that by properly studying and preparing the structures, by modeling the data on the resistance and stability requirements, they can be demolished using explosives under conditions of success and full safety.

When demolishing a structure, the following requirements may appear:

- the structure must be fall down in a given direction;
- the structure must fall on itself;
- the structure must be overturned with a shortened length in a certain direction.

The choice of one of these variants is conditioned by the physical state of the construction, the existence of objectives in the vicinity of the demolition construction, the possible effects of demolition on these objectives. The demolition process chosen must meet the following requirements:

- directing the fall to protect the nearby active constructions and maintain the production process;
- protecting buildings near the target, against seismic action, shock wave, and throwing concrete or metal pieces under the effect of the explosion.
- destroying the integrity of the construction, so that the dismantled elements can be transportable or loaded with mechanical means;

The basic idea of a demolition is that the destructive effect on the objects to be protected is negligible, the number of elements destroyed by the blast being as small as the quantities of explosives that shoot at once. The explosive necessary to dismantle a certain constructive parts, is dependent on the type of explosive used, the material to be blast, the type of construction to be demolished, and the geometry of the load location (Laszlo et al, 2005).

#### 3.2. The furnace demolition process

The demolition of the furnace was done by fall it down simultaneously with the other construction elements - the pipe and the cleaning bag. In view of the demolition of the furnace and the orientation of its fall in the desired direction it was chosen the solution of the sectioning of the constructions in two planes, by creating detachable cuttings.

Thus, a first detachment was carried out in the upper area, in the four metal posts supporting the platforms and the furnace loading device between the +6.0 m elevation and the +13.00 m elevation (shaped charge explosive apply on the metallic structure).

The largest opening of the cut was oriented from the direction of tip over to the back of the furnace

A second detachment cut was carried out in the lower zone by the creation of cutting sections in reinforced concrete support pillars of the cleaning bag above +1.0 m from ground level (dynamite explosives placed in the perforated holes in the reinforced concrete pillars).

### 4. Preparatory stages for demolition of structures

In order to overturn the furnace, pipe and cleaning bag, a series of preparatory works were carried out (Laszlo et al, 2014).

### *Furnance body*

- pre-cutting of the outer tubing supported by the furnace and the foot of the estacade;
- decommissioning of the walls as well as the roof of the furnace hall;
- separating the connections between the furnace platforms and the lift tower;
- decommissioning of all facilities and equipment between  $\pm 0.0$  m and  $+13.0$  m level around the 4 main pillars;
- decommissioning the floor from the  $+6.0$  m elevation of the furnace hall in front of the pillar pair in the downward direction (Fig. 2);
- in order to overturn the furnace, it was created a cut on the pair of front pillars in the direction of fall by three breaking sections between the elevation  $+6.0$  m and  $+13.0$  m (Fig 4);
- for the creation of the cut, the metal pillars were first omitted by oxyacetylene flame cutting with  $2 \times 0.50$  m profile on the front and rear sides (Fig. 3, a);
- on the other two lateral sides of the post, a cut of the profile is executed in front of the front and rear sides (Fig. 3, b);
- on the pair of rear pillars opposite to the fall direction, the profile on the two side faces and the rear face was cut at the level of the front lower section of the front pillars (Fig. 3, c);

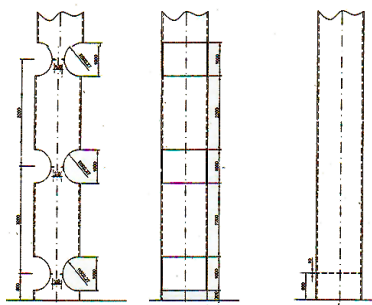


Fig. 3. Preparing metal front pillars (a, b) and rear (c)



Fig. 4. Completing the preparation of metal pillars

### *Cleaning bag*

- the first pair of pillars from the falling direction and the third pair of pillars (Fig. 5) were previously cut off to the cleaning bag. From the end of the drain mouth was cut 2 m in height;
- for the creation of the detachment cut, in order to overturn the cleaning bag, fracture sections were created, in which purpose holes were drilled in pillars as follows:
  - pile pair,  $1.5 \times 1.5$  m section, from the drop direction, a group of  $4 \times 3$  holes starting at 1.0 m from the base of the pillar, a second group of  $4 \times 3$  holes drilled at a distance of 1.0 m from the first group of holes and a third group of  $4 \times 3$  holes drilled at a distance of 1.0 m from the second group of holes (Fig.5);
  - the pile pair, with the  $1.5 \times 1.5$  m section opposed to the fall direction, is slanted by mechanical means on the back, at  $+3$  m distance above ground level, by  $\frac{1}{3}$  of pillar thickness, and the unveiled metal structures are cut.



Fig. 5. Prepare concrete columns for supporting the purge bag



Fig. 6. Shaped charge explosive type CCL 30 - 200

## **5. Explosive charges. The type of explosive, mode of application and initiation**

Explosive charges are dimensioned according to the type of material and section of the construction elements to be sectioned. For the cutting of the breaking sections on the metal profiles, shaped explosive charges CCL 30-200 have been used. These loads are delivered in the form of bars with a length of 0.200 m and have an explosive load of 0.230 kg. (Figure 6). A dynamite explosive was used to cut the columns of the cleaning bag support.



### 5.1. Explosive charge construction and initiation mode

Since the thickness of the posts of the pillars was 40 mm, two explosive loads applied on both sides of the soles were used. To fix the shaped loads CCL 30-200, it was intended that they be symmetrically placed so that the cumulative action of the explosive work in the same plane (Fig. 7). To ensure the simultaneous initiation of the shaped explosive charges on the two faces of a cutting section, have been initiated at both ends with a 12 g / m detonating cord line overlapping on the shaped explosive bar. In a breakage section on a metal pole, the two-sided detonating lines were chained from one load to the other and initiated with a detonator of the Nonel non-electric system. The destructive effect of the shaped explosive charges was previously verified by a test shot on a representative profile cut from the structure of the metal support pillar. (Fig. 8).

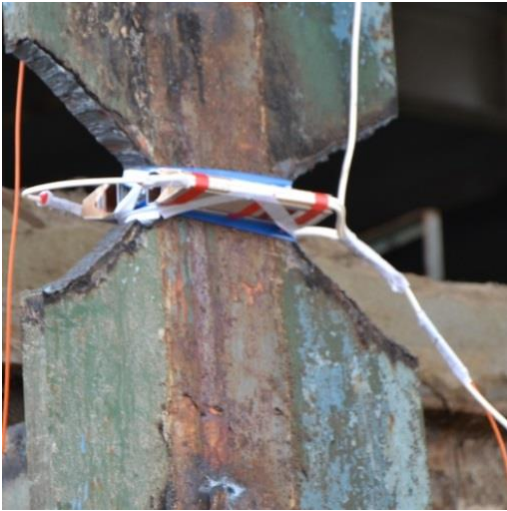


Fig. 7. Explosive application method on metal pillar profile



Fig. 8. Testing the destructive effect of the shaped explosive

### 5.2. Explosive charge on the furnace metal pillars in the direction of fall (Laszlo et al, 2014, Laszlo et al, 2005):

- metal profile thickness,  $Gt = 0.040$  m;
- cutting length of one-sided section,  $L = 0.380$  m;
- number of cuts in a breakage section,  $Nc = 2$ ;
- number of breaking sections per pillar,  $Nb = 3$ ;
- the shaped explosive charge applied in mirror, two pieces on each side of the profile. Total 8 pieces at one breaking section;
- number of shaped charges per pillar  $N = 8 + 8 + 8 = 24$  pieces.

### 5.3. Explosive charges on concrete pillars from the cleaning bag (Laszlo et al, 2014, Laszlo et al, 2005):

- pillar pair with  $1.5 \times 1.5$  m section;
- burden,  $W = 0.350$  m;
- the distance between holes in a row,  $a = 0.30$  m;
- number of vertical rows,  $N = 3$ ;
- number of holes per pillar,  $N = 12 + 12 + 12 = 36$  holes;
- hole length,  $lg = 0.90$  m;
- explosive charge per hole,  $Qh = 0.150$  kg Dynamite;
- explosive charge per pillar  $Qp = 5.400$  kg Dynamite.

Upon demolition of this furnace, 48 pieces of shaped charges were used. = 11,400 kg. CCL type 30-200 and 10.8 kg. of Dynamite explosive type. At the execution of the blasting, the explosive charges were protected with wire net and geotextile cloth. The purpose of these protections was to minimize the phenomenon of throwing pieces of material under the action of the explosion.

### 5.4. The order of detonation of explosive charges

In order to fall over the assembly of furnace, pipe and cleaning bag, was used the following order to initiate the explosive loads:

1. Breaking sections of the front row pillars, those supporting the cleaning bag.

## 2. Cutting sections of the front row pillars, those supporting the furnace.

As can be seen from the delay order, it was chosen to first detonate the cleaning bag support pillars and then the metal pillars from the furnace falling down direction.

This was because, prior to the commencement of the furnace movement, it was necessary to move the center of gravity of the pipe towards the direction of the furnace overturning. Since the pipe is support on the cleaning bag, by blasting the cleaning bag pillars in advance, the pipe it has been moved to the direction of overturning together with the whole assembly.

## 6. Static modeling of the furnace assembly, pipe and cleaning bag

In order to verify structures in terms of resistance and stability requirements, after loosening or removing some sections, the data was processed through a structural analysis program - Axis VM 12. (Laszlo et al, 2014).

In the spatial analysis of the structure, the static scheme was introduced with the sectional characteristics related to the cross-sections of the component elements, and on the parts that were reduced from the pillars section (in the place of the explosive loads), the sectional characteristics of the cutting details have been taken into account. In the calculations, only the assumption of own weight loading was taken into account without any external disturbance of the structure. In the modeling it was considered that there are no stresses due to a forced assembly and when demolition is performed the structure of resistance has no connection with the other equipment in the area, being considered free in the structural analysis.

After checking the resistance structures according to the new constructive data, it was found that they meet the conditions of resistance and stability. After modeling the situation of the realization of the detachable cuttings using the energy of the explosives, it was found that the structures would overturn in the intended direction (Fig. 9,10,12).



Fig. 9. Molded shape after furnace decommissioning by classical methods



Fig. 10. Molded preparatory work for overturning the furnace



Fig. 11. Static modeling of the furnace assembly,





Fig. 12. Furnance assembly after blasting operation

## 7. Conclusions

The constructive assemblies of the furnaces and generally the constructions made of metallic structure, will be in the future the object of demolitions activities by blasting works.

The static modelling of the structures can determine the preparatory work consisting in the cutting of the non-important elements and the reduction of the section of the supporting elements, which will reduce the size of the explosive loads. In this way massive structures can be demolished only by using several tens of kilos of explosive.

Practical experience also highlighted the superior net results obtained by using shaped explosive charges in order to cut metal structures. With the use of these loads, small explosive quantities are involved but which have a maximum effect in terms of sectioning and a minimum effect from the point of view of the air shock wave and noise.

Also, using the computer modelling of the works for the preparation of structures according to the chosen demolition concept, the blasting works are executed under conditions of efficiency, quality and security.

## References

- Laszlo, R., Ille, I.M., Fisgus, C., *Technical documentation for demolition by blasting of furnaces inside the companies Siderurgica SA, Hunedoara and CS Resita, Petrosani., Romania, (2000- 2005).*
- Laszlo, R., Eckehardt, Z., Ille, I.M., *Demolition of metal structures. Experience gained in the demolition of five furnaces on the premises of Siderurgica Hunedoara Company, Brighton, U.K., (2005).*
- Laszlo, R., Fisguss, C., Galvitu, M., *Technical documentation for emolition by blasting works with classical works of furnace no.6 from the premises of Arcelor Mittal Galati, Petroșani, Romania, (2014).*

## Fans, specific operational parameters of industrial ventilation installations

Gherghe Ion<sup>a\*</sup>, Cioclea Doru<sup>a</sup>, Tomescu Cristian<sup>a</sup>, Rădoi Florin<sup>a</sup>,  
Boantă Corneliu<sup>a</sup>, Chiuзан Emeric<sup>a</sup>

*<sup>a</sup>National Institute for Research and Development in Mine Safety and Protection to Explosion, INSEMEX, 32-34 G-ral Vasile Milea street, Petroșani, 332047, Romania*

---

### Abstract

An industrial ventilation system is started each time in a work place occur noxious, in order to maintain a safe, healthy, productive and comfortable environment in conditions of work hygiene, health and safety of workers, where this need is determined not only by the human occupation level, but also by other factors, such as production processes.

For choosing a proper ventilation installation, there is needed an analysis of the workplace to be ventilated so that the chosen solution to solve the problem of noxious exhaust and to respect the comfort of the workers.

In this paperwork, there are presented different types of fans used in industrial ventilation, the operational parameters, the air state parameters and the aerodynamic parameters of ventilation pipes, because they have the greatest influence on the operation of a ventilation installation.

*Keywords:* industrial ventilation, parameters, fans;

---

### 1. Introduction

Designing and building an individual ventilation system should harmonize comfort requirements with the user's ventilation system management, without adversely affecting other system functions. Choosing the most suitable ventilation system for a given situation is largely the key to satisfactory operation. The situations that come into practice are, however, so numerous, complex and varied, the industrial processes in such a rapid evolution, and the need for ever greater comfort, to systematize the different situations that appear and to attach to each category the most suitable ventilation system would be both difficult and impractical.

### 2. Technological air systems

Industrial air technology includes measures for the indoor environment (general and local), measures to prevent hazardous emissions resulting from industrial processes from evacuation to the outside, such as transport and purification technologies, and measures to prevent or minimize the damage caused by accidents, fires or explosions. Industrial air-conditioning systems can be classified into two categories: industrial ventilation and air-processing technologies. Within this system is part of (Al. Cristea, 1968), (D. Cioclea, 2013):

- **Air conditioning systems that control** air and environmental quality for both human factor and process.
  - **General ventilation systems** where some internal parameters are only partially controlled. Target levels are usually lower than those for air conditioning.
  - **Local ventilation systems** are used for locally controlled areas. These systems are based on local capture of contaminants.
  - **Process ventilation systems** are designed to maintain defined conditions to ensure process performance (eg, paper machine's fume cupboard).
- 

\* Gherghe Ion. Tel.: + 40-254-541-621; Fax: +40-254-546-277.  
E-mail adress: ion.gherghe@insemex.ro

### 3. Fans

Fans are rotary machines for increasing the air pressure (static pressure) transformed from the mechanical energy received on the motor shaft. The main elements of a fan are the rotor, casing and rotor system (Al. Cristea, 1968).

Following the direction of the airflow in the fans, they are classified into centrifugal or radial fans and axial fans.

Depending on the operating principle, fans may be (Fig. 1) (Al. Cristea, 1968), (I. Matei, 2000), (Băltărețu Raul, 1980):

- axial, where the air enters directly into the fan and is centred on the axis of rotation of the engine. Due to the relatively high rotation speeds compared to centrifugal fans, the axial fans are louder;
- centrifugal, in which the air penetrates axially, makes a right angle and then moves radially outwardly under the action of centrifugal force. The rotor blades may be straight or curved front or rear relative to the direction of rotation;
- bifurcated are usually auxiliary fans that are designed so that the motors operate in fresh air while the rotor is driving vicious air;
- combined (mixed) flow are mainly centrifugal mounted in such a way that they can operate in the same way as the axial ones, the air enters the axial fan and leaves the fan at an angle that may vary from  $30^\circ$  to  $90^\circ$ ;

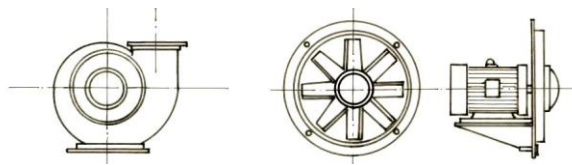


Fig. 1. Centrifugal and axial fans: a) centrifugal fan; b) axial fan

#### 3.1. Axial fans

Axial fans owe their name to the fact that the air movement is along the fan axis. Generally, axial fans are used at high air flows and at low pressures. An axial fan consists of a tubing with a shaft or hub on which a number of blades are fixed. (William A. Burgess, 2004)

**Fans with propellers** are common ubiquitous air fans for homes, offices and hot work environments (Fig. 2).

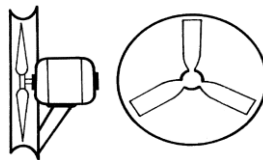


Fig. 2. Fans with propellers

**Tubular fan with propellers** (Fig. 3) are essentially a more complex version of propeller fans that have been modified so that they can be inserted into a duct (William A. Burgess, 2004).

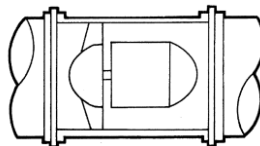


Fig. 3. Tubular fan with propeller

Vane-axial (Fig. 4) are tubular fans that have been modified by adding air-guiding blades to the engine housing behind the fan blades (William A. Burgess, 2004).

Such fans can operate at static pressures of up to 2000 Pa and are therefore suitable for use in local exhaust systems, being used as fresh air intake fans (William A. Burgess, 2004).

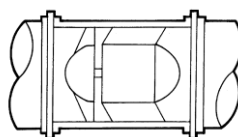


Fig. 4. Tubular fans with control blades

### 3.2. Centrifugal fans

Centrifugal fans use a rotor to increase the flow of air. As the air moves from the rotor hub to the blade tips, it gains kinetic energy.

A centrifugal fan works on a totally different principle than the axial ones. The centrifugal word means flowing from the centre (Fig. 5), (Al. Cristea, 1968).

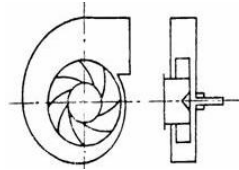


Fig. 5. Typical centrifugal fan (horizontal air suction and vertical discharge)

After the number of suction mouths, the centrifugal fans are single-aspirating and double-aspirating and, after the total developed pressure, they are classified in (Al. Cristea, 1968):

- low pressure fans (up to 100 daPa);
- medium pressure fans (up to 500 daPa);
- high pressure fans (up to 1000 daPa), above this pressure, their construction must to be modified, entering into other categories of machinery;

### 3.3. Bifurcated ventilators

Bifurcated ventilators are typically auxiliary fans that are designed so that the motors operate in fresh air while the rotor circulated vicious air. To do this, the fan casing is designed to allow the air to pass anywhere as the engine is encapsulated (Fig. 6) (William A. Burgess, 2004).

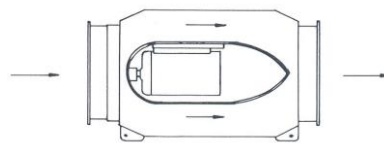


Fig. 6. Bifurcated fans

### 3.4. Combined flow fans (mixed)

Mixed rotation fans are hybrid fans in the sense that they are typically mainly centrifugal mounted in such a way that they can operate in the same way as the axial ones. With these fans, the air enters the axial fan and leaves the fan at an angle that may vary from 30 ° to 90 °. The flow of air through the rotor thus becomes partially centrifugal (Fig. 7) (William A. Burgess, 2004) .

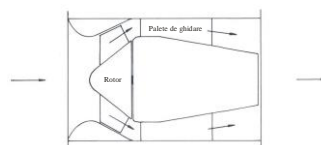


Fig. 7. Mixed air flow fan

## 4. Functional parameters of industrial ventilation installations

The functional parameters defining the performances of a fan are: airflow, pressure, speed, power and efficiency. In addition to functional parameters, it is also necessary to know the parameters of the air condition (temperature, humidity, absolute pressure, air velocity) and the aerodynamic parameters of the ventilation ducts (the geometric elements of the column, the aerodynamic resistance of the column, the unit coefficient of loss of air) as it mostly determines the operation of a ventilation system.

### 4.1. Functional parameters of a fan

The functional parameters of a fan are: airflow, pressure, speed, power, output, voltage (Al. Cristea, 1968), (I. Matei, R. Moraru, 2000), (Băltărețu Raul, 1980), (INCD-INSEMEX Study, 2013).

**Fan flow** - is the number of cubic meters of air trained in the unit of time in the suction mouth, expressed in  $\text{m}^3 / \text{h}$ .

The air flow inside a duct or the suction and discharge port of the fan is determined by the geometrical elements of the pipe (section of the pipe) and the air flow rate therein.

The formula for calculating the air flow is given by the relationship:

$$D = s \cdot v \cdot 3600 \quad [\text{m}^3/\text{h}]$$

Fan pressure - is the actual pressure produced by it and expresses the increase in fan pressure between the suction and discharge ports. The total fan pressure is equal to the sum of the total pressure measured at suction and fan discharge (dynamic pressure and static pressure).

#### 4.1.1. The absorbed power of a fan (Pa)

The total power of a fan is the power absorbed (Pa) from the power source required to provide effective power to the fan shaft and is determined with:

$$Pa = \sqrt{3} \cdot U \cdot I \cdot \cos \varphi \quad (\text{kW})$$

depending on the values obtained from the measurements for the current, the electrical voltage and the power factor.

#### 4.1.2. The useful power specific to the ventilation (Pu)

The useful power of a fan is the useful mechanical work done in the time unit for air circulation and is given by the expression:

$$P_u = (Q \times H) / 102 \quad (\text{kW}) \quad \text{or} \quad P_u = (Q \times H) / 1000 \quad (\text{kW})$$

where: Q - fan flow rate [ $\text{m}^3/\text{s}$ ];

H - Fan depression [mm of water] or [Pa]

#### 4.1.3. Fans speed and drive motors

The speed of an engine or fan ( $n_M$ ,  $n_V$ ) is the circular motion of the rotor around its axis or from a fixed point made to the point of departure and expressed in rpm.

$$\frac{n_M}{n_V} = \frac{D_V}{D_M}$$

where:  $n_M$ ,  $n_V$  - engine and fan axle rotations (rot / min)

$D_M$ ,  $D_V$  - pulley diameters on the motor and fan shaft (m)

#### 4.1.4. Fan yield

Fan efficiency - is the ratio between the useful power and the absorbed power received at the fan shaft, determined with:

$$\eta = (N_u / N_a) = [(Q_v P_v) / 1000 N_a] \times 100 \quad [\%]$$

in which:

$Q_v$  - airflow rate developed by the fan,  $\text{m}^3/\text{s}$ ;

$P_v$  - Fan pressure, Pa, total or static to yield total or static efficiency;

$N_a$  - power absorbed at engine spindle, kW.

The rational operating range of a fan can be ensured by observing the stable operating condition ( $P_v \leq 0,9 P_{\max}$ ) and by an economical operation ( $\eta_v = 0,85 \eta_{\max}$ ).

### 4.2. Air condition parameters

Air condition parameters include: air temperature, air humidity, absolute air pressure and air flow rate in the duct. These parameters are the most important characteristics of the ambient air, having a direct influence on human health and on the effectiveness with which they operate (Al. Cristea, 1968), (I. Matei, 2000), (Florica Băltărețu, 1987):

- **Air temperature** - is measured with an ordinary thermometer, a dry tank or electronic devices.

- **Relative humidity** - the ratio between the mass of water vapour contained in an air volume at a given temperature and the mass of the vapour required to saturate the same volume of air at the same temperature and expressed as a percentage (% RH).

- **Absolute air pressure** - Barometers are devices for measuring absolute static air pressure.

#### 4.2.1. Air flow rate

Air velocity in pipelines is chosen according to the destination of the plant. In systems in social, cultural, administrative, commercial, sanitary, residential and similar buildings, the air velocity in pipelines is limited by noise conditions. Installations in industrial halls, which usually drive large airflows and can operate under less severe silences, are sized on the basis of higher air velocities.

In order to determine the required speeds for the transport of solid particles in pipelines, Dalla-Valle's approximate formulas can be used, namely (D. Cioclea, 2013):

- for horizontal pipelines:

$$v = 9 \frac{\gamma_p}{\gamma_p + 16} d_p^{0,4} \quad (\text{m/s})$$

- for vertical pipelines carrying the particles upside down:

$$v = 20 \frac{\gamma_p}{\gamma_p + 16} d_p^{0.4} \quad (\text{m/s})$$

in which:

$\gamma_p$  - is the specific weight of the transported material in kg/m<sup>3</sup>;  
 $d_p$  - maximum particle size in mm.

The choice of air velocity in pipelines should always be done with discernment. First, the functional criterion has to be considered.

Also, the value of the velocity of the air flow in the column of tubes can be determined by the relation (I. Matei, 2000), (Florica Băltărețu, 1987):

$$V = \sqrt{\frac{2ghd}{\rho}} \quad (\text{m/s})$$

in which:

$g$  - gravitational acceleration m/s<sup>2</sup>  
 $hd$  - the final mean dynamic pressure (pressure), Pa;  
 $\rho$  - air density, kg/m<sup>3</sup>

#### 4.3. Aerodynamic parameters of the ventilation ducts

These parameters include: the section of the pipeline, the unitary aerodynamic resistance  $R_0$  and the unit air loss coefficient  $K_0$  (I. Matei, 2000), (Florica Băltărețu, 1987), (D. Cioclea, 2013).

##### 4.3.1. Geometrical elements of pipelines

The shape of the industrial ventilation ducts is chosen depending on the available space, the possibility of incorporating them in the structure of the building, the airborne suspension particles. They are round or square in shape because they have the highest transport capacity (m<sup>3</sup>/h of air) per square meter of lateral surface of the pipe. Also, the air must be run on the shortest way, with a mini-local resistor, and the pipe should be of an appropriate average length.

Measure the geometrical elements of the pipe (width, height, diameter) depending on the cross-sectional shape, calculate the free surface and their perimeter using the mathematical relations of the pipe shape.

##### 4.3.2. Aerodynamic resistance of the ventilation columns

To determine the aerodynamic resistances specific to the  $R$ ,  $R_0$ ,  $R_C$ , aerodynamic columns, the Atkinson laws (Al. Cristea, 1968), (I. Matei, 2000), (Băltărețu Raul, 1980), apply:

$$p = \alpha L \frac{P_e}{A^3} Q^2 \quad [\text{Pa}] \quad \text{or} \quad p = \frac{\alpha L P_e}{A^3} \quad [\text{N s}^2/\text{m}^8 \text{ or } \text{kg}/\text{m}^7]$$

where:  $\alpha$  represents an aerodynamic friction coefficient, depending on the density of the air and expressed in density units, kg/m<sup>3</sup>.

To determine the aerodynamic resistance of an air column, the relationship  $p = RQ^2$ , which is the square law of the fluid flow, applies.

The unitary aerodynamic resistance  $R_0$ , characteristic of leaky columns, is determined by the relationship:

$$R_0 = (P_1 - P_2) / Q_m^2 \quad [(\text{daPa} \times \text{s}^2/\text{m}^6)/\text{m}]$$

in which:

$P_1$  - represents the pressure measured at a point of the column, to the fan, daPa;  
 $P_2$  - represents the pressure measured at a point in the column, to the zone of release of harmful gases, daPa;  
 $Q_m$  - air flow rate in the air column, between the two measuring points, m<sup>3</sup>/s;  
 $L$  - the length of the column between the measuring points, m.

##### 4.3.3. Unit coefficient of air loss

$K_0$  - represents the difference between the air flow rate developed by the fan and the air flow rate at the column air intake or clear air exhaust in the the area of the formation of noxes and expressed in m<sup>3</sup>/s of leakage per one meter of column. Air losses mean either airflows drawn along the column or column airflow outflows along its entire path, and is determined by the relationship (I. Matei, R., 2000), (Florica Băltărețu, 1987), (D. Cioclea, 2013):

$$K_0 = \frac{3(Q_1 - Q_2)(P_1 - P_2)}{2L(P_1^{3/2} - P_2^{3/2})} \quad [\text{m}^3/\text{s}/\text{m} \text{ at the pressure } P_1 - P_2]$$

If at the end of the column opposite to the fan, the pressure is null, ie  $P_2 = 0$ , there is obtained:

$$K_0 = \frac{3(Q_1 - Q_2)}{2L\sqrt{P_1}} \quad [\text{m}^3/\text{s}/\text{m} \text{ at the pressure } P_1]$$

## 5. Conclusions

1. Technological air processing systems may be: air conditioning systems that control air and environmental quality for both human factor and process; general ventilation systems where some internal parameters are only partially controlled. These systems are based on local capture of contaminants; Process ventilation systems are designed to maintain defined conditions to ensure process performance (e.g., paper machine fume cupboards).
2. By principle of operation the fans can be axial, centrifugal, bifurcated and combined (mixed);
3. Parameters defining the performances of a fan are: air flow, pressure, speed, useful power, power absorbed, and efficiency. The air condition parameters in a pipe are the temperature, humidity, absolute pressure and air circulation speed, and the aerodynamic parameters of the ventilation ducts are: the geometric elements of the pipe, the unitary aerodynamic resistance  $R_0$  and the unit air loss coefficient  $K_0$ ;
4. The unitary aerodynamic resistance  $R_0$  - determines the characteristic pressure loss for a given air flow rate over a given length and is obtained from measurements of pressure, temperature, absolute pressure and airflow velocity measurements using calculation relations;
5. The unit air loss coefficient  $K_0$  is obtained from measurements of pressure, temperature, absolute pressure and air flow velocity and represents the difference between the air flow rate developed by the fan and the air flow rate at the suction nozzle air in the column or clean air discharge in the area of the formation of emissions and expressed in  $\text{m}^3/\text{s}$  of leakage air per one meter of column.

## Acknowledgements

This paper was developed within the Nucleu-Programme, carried out with the support of MCI, project no.PN 18170202

## References

- Băltărețu, F., Matei, I., *Practical guide for the design and verification of partial air-conditioning systems*, Ministry of Mines, Petroleum and Geology-1987, pp. 39-61
- Băltărețu, R., Teodorescu, C., Gonteanu, Z., *Aeraj minier*, Editura Tehnică București 1980, pp 55-90, pp 271-274, (1980).
- Cioclea, D., Lupu, C., *Guide for Sizing of Industrial Ventilation Installations*, INSEMEX Publishing House, 2013, pp 102-109, pp 133-134, (2013).
- Cristea, A., *Ventilation and air conditioning, (in Romanian)*, vol.I, Technical Publishing House Bucharest, Romania, 1968, pp 351-352, pp 466-487, (1968).
- Matei, I., Moraru, R., ș.a., *Environmental Engineering and underground ventilation, (in Romanian) Technical Publishing House Bucharest, Romania*, ISBN 973-31-1496-0, 2000, pp 290-303, pp 346-357, (2000).
- Methodology for verifying ventilation systems operating or operating potentially explosive and / or toxic environments - INCD-INSEMEX Study*, Petrosani, (2013).
- William, A. Burgess, Ellenbecker, M.J., Treitman, R.T., *Ventilation for Control of the Work Environment*, Second Edition, Copyright © 2004 John Wiley & Sons, Inc., pp 283-285, (2004).



## The impact on the environment produced by the methane gas released in the Jiu Valley coal mines

Ianc Nicolae<sup>a\*</sup>, Cioclea Doru<sup>a</sup>, Gherghe Ion<sup>a</sup>, Radoi Florin<sup>a</sup>, Chiușan Emeric<sup>a</sup>,  
Matei Adrian<sup>a</sup>, Dragoescu Razvan<sup>a</sup>

*<sup>a</sup>National Institute for Research and Development in Mine Safety and Protection to Explosion, INSEMEX, 32-34 G-ral Vasile Milea street, Petroșani, 332047, Romania*

---

### Abstract

Mining industry is characterised by specific work conditions, imposed by natural particularities and by the characteristics of the production process. They require a series of complex and specific measures, which are intended to create normal work conditions, without bringing any harm to workers, by accidents or occupational diseases.

Due to the fact that methane, entity present in coal mining, represented in time the main factor of hazard and a major concern in researching and gaining higher safety conditions. Worldwide, intensive research aiming to provide knowledge on the elements connected with the occurrence and prevention of methane hazard, demonstrates that no price is too high for rewarding research for managing underground health and safety.

On the other hand, in compliance with the Intergovernmental Panel on Climate Change (IPCC), 17% of the global warming effect is generated by methane. Methane comes from a series of anthropogenic and natural sources,

Both types of sources contribute to the increase of underground methane concentration, the major contribution being of natural ones. Methane is rapidly transformed into less hazardous molecules which enter in other transformation cycles. Methane's contribution to global warming is significant, its' global warming potential being over 20 times higher than the one of carbon dioxide.

Based on the available data presented in Romania's national communication on the manner of applying the provisions of the Framework convention on climate changes, there is a real capacity for using specific measures for applying the provisions of the Kyoto Protocol.

Same data reveal the fact that there can be performed an additional gas emissions decrease of minimum 6%, compared to the official engagement communicated by Romania in the European integration process.

Methane releases into the atmosphere following the exploitation of coal have double ecologic impact, participating in the destruction of the ozone layer and in contributes to the enhancement of the greenhouse effect. At the same time, methane released into the atmosphere in coal mining, may be used by miners as a primary power source for covering the own power requirements of it may be used for commercial purposes.

*Keywords:* industry, atmosphere, mining, methane;

---

### 1.Introduction

The need for degassing must be related to an increase in underground security, as well as to the reduction of ventilation costs due to the movement of the quantities of methane released, respectively the possibility of rational utilization of methane, while reducing the environmental impact and, implicitly, global warming(Ianc N 2015).

The application and valorisation of the local degassing was implemented at the Lupeni and Vulcan mines.

Reducing the impact on the underground environment by degassing.

---

<sup>\*</sup>Ianc Nicolae. Tel.: +40-254-541-621.  
E-mail address: nicolae.ianc@insemex.ro.

## 2. Methods and systems for reducing the impact on the underground environment

### 2.1. Centrifugal degassing

Establishing the opportunity for mine degassing involves a detailed analysis of the complex of factors influencing methane emissions, a methane emission forecast, a diversified ventilation factor analysis, a clear knowledge of deposit reserves and exploitation dynamics (Băltărețu and Matei, 1987).

The factors determining the necessity of degassing the mass of rocks at the mine, sector, coal bed or mine workings level, are represented by:

- installed ventilation conditioning;
- air flow rates in underground and in the areas with large methane releases;
- additional air reserve determined according to the absolute methane flow at the permitted concentrations of the norms;
- the balance of absolute and relative methane flows and the ratio of these parameters to the installed and additional air capacity of the mine;
- special situations of preparation and exploitation (loose cuts, jomp exploitation, etc.).

The most used process is the capture and drainage of the gases with the help of some pipe sections introduced into the exploited space.

At C.N.H. - Petrosani, central degassing applies to the Lupeni and Livezeni mines.

Centralized degassing installations are located at the mine surface, equipped with 4 groups of vacuum pumps for gas suction, are of Polish origin and have the following characteristics:

- flow:  $Q = 25 \text{ m}^3/\text{min}$ ;
- maximum suction depression:  $H = 4.000 \text{ mm H}_2\text{O}$ ;
- maximum discharge pressure:  $P = 3.000 \text{ mm H}_2\text{O}$ ;
- engine power:  $N = 75 \text{ kw}$ ;
- Speed:  $n = 735 \text{ rpm}$ .

The degassing of the above-mentioned units was accomplished by capturing methane from wells drilled underground and by capturing methane from old mine workings (the space exploited). The research carried out by INSEMEX Petrosani over the years on the degassing of the rock mass, led to the elaboration of degassing frameworks depending on:

- type of mine workings;
- exploitation method;
- the thickness of the coal layers;
- Tilt of coal strata.

Among the existing degassing methods, the most used are:

- the "C" frame method (Fig.1.a) - which applies when performing preparation mining works which crosses a thick coal layer or a package of layers;
- the "G" type method (Fig .1.b) - which applies to coal layers with a slope of up to  $35^\circ$ , which is operated with frontal stopes, the withdrawal method;
- the H-type frame method (Fig.1.c) - applies to coal-bed layers with tilts up to  $35^\circ$  which are operated with frontal stopes, the advance method.

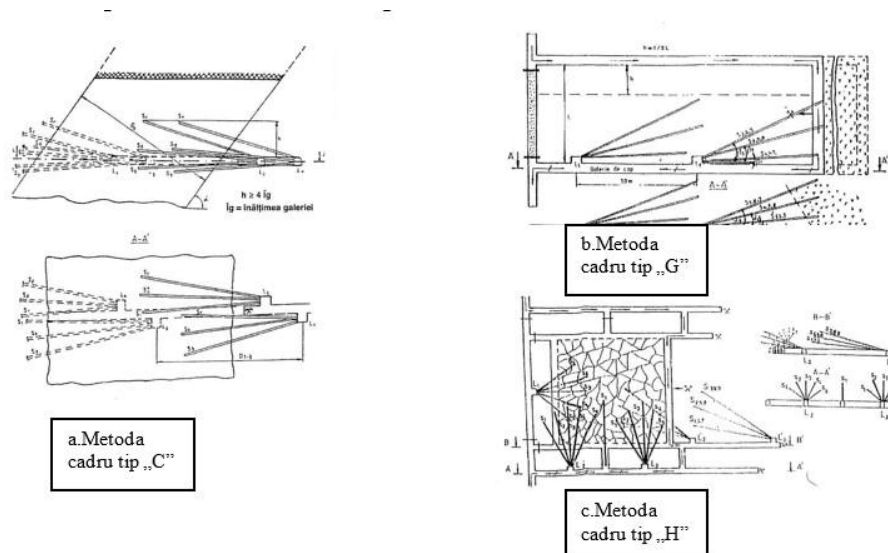


Fig. 1. Fractionation methods applied to mines in the Jiu Valley

The wells for degassing are run based on a program (project). The geometrical characteristics of the well holes in the degassing frame methods are presented in table 1.

Table 1.

Characteristics	Units	Values ranges for degassing frame schemes								
		„A”	„B”	„C”	„D”	„E”	„F”	„G”	„H”	„I”
Elementary tubing diameter	mm	100-125	100-125	100-125	100-125	100-125	100-125	100-125	100-125	100-125
Cementitious sealing tube length	m	6-10	6-10	6-10	6-10	6-10	6-10	6-10	6-10	6-10
Number of holes in a location	piece	1-2	Depending on the panel length	2-6	4-6	4-8	1	2	9-16	5-10
Diameter	mm	65-86	65-86	65-86	65-86	65-86	65-86	65-86	65-86	65-86
Length	m	20-40	60-100	60-100	60-100	60-100	60-100	60-100	60-100	60-100
Angle of inclination, $\alpha_g$	(°)	2-4	-	$\alpha_{2,4}=0$ $\alpha_3=10$ $\alpha_{1,5}=15-20$	Function of rel. H-h=4a	10-90	$\alpha_1=\alpha_5$	$\alpha_1=\alpha_5$	$\alpha_1=10$ $\alpha_2=15$ $\alpha_3=20$	$\alpha_1 \leq 10$
Angle of direction, $\beta_g$	(°)	0-45	10	0-10	40-120	45-125	90	90-10	0-90	0-90
The distance between the soles of the adjacent holes	m	-	-	10	10	10	-	-	10	10

In Jiu Valley mines, for capturing the methane from the old mine workings (the exploited space), the dams are used to isolate these areas. The results of the capture from the old mine workings (the Livezeni mine) depend essentially on the tightness of the isolation works. (Băbuț. G et al.,2000) The release of methane in the stressed areas drops rapidly behind the stope but never ceases altogether, as long as the methane levels are still present. As a result, variable quantities of gas, which occupy the gaps in the exploited space and which can reach the airflow, are always released in the inactive works (Lupu C.2007; Tomescu C. 2015).

In view of the above, for methane capture under the best conditions it is recommended:

- the closure of the works in which the methane is about to be captured, has to be made with as few as possible dams;
- Depending on the existing possibilities, dams' positions must be chosen before closure, so that they are located in areas with compact rocks and which are not or cannot come under the influence of exploitation;
- The thickness of the dams is slightly influencing their aerodynamic strength. The minimum thickness is given by the mechanical strength the dam must have, depending on the load to which it is subjected by the surrounding rocks.

For the arrangement of the degassing sites (niches), the following steps are taken:

- digging of the degassing niche;
- Drilling and sealing of well holes;
- endowment of degassing locations (niches).

The equipment for a degassing niche must necessarily include the components shown in Fig. 2 (1-capture tube, 2-valve for methane closure, 3-nozzle for injection of cement milk, 4-nozzle for measurement and control 5-pipe connection hose, 6-gas collector and liquid separator, 7-flange, 8- nozzle separation valve, 9 main gas pipe).

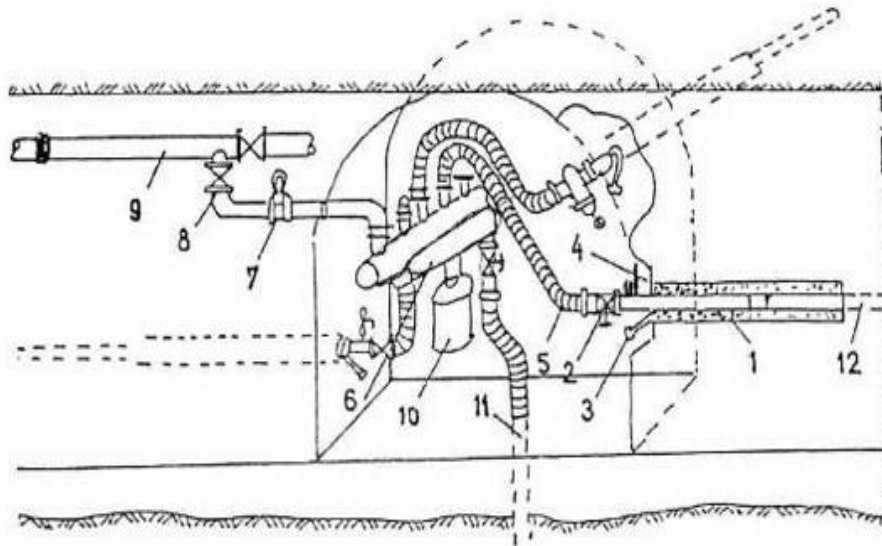


Fig.2. Arrangement and equipping of clearance sites

## 2.2. Local degassing applied to Jiu Valley mines

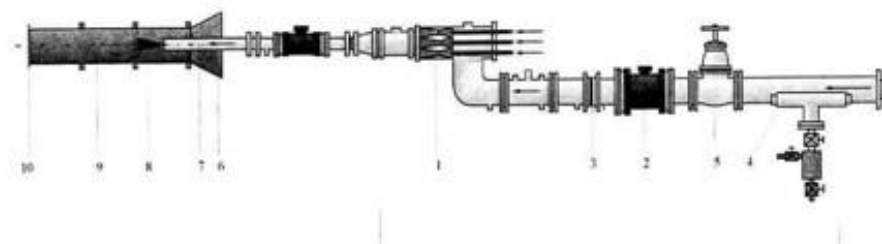
- Local methane capture and drainage can be applied under the following conditions;
- Predicted gas quantities can be drained with ejectors and diluted to the maximum percent methane concentrations permitted in the evacuated air stream;
- it is not possible to ensure the permanent maintenance of methane concentrations above 30% vol.

The forecast of methane emissions as well as the situation of releases of gas from underground works do not justify the desirability of central degassing.

A local degassing plant has the following components (Fig.3):

- compressed air degassing ejector;
- Devices and devices for measuring, protecting and regulating specific parameters;
- mixing and dilution chamber.

The compressed air degassing ejector is the basic equipment of the plant that develops the energy needed to capture and drain the gas.



- |                              |   |
|------------------------------|---|
| 1-Ejector degazare           | 6-Tronson de suplimentare a debitului de aer în camera de diluare |
| 2-Dispozitiv paraflacăă      | 7-Tronson refulare  |
| 3-Dispozitiv Royal-Duth      | 8-Deflector gaze  |
| 4-Separator apă-detritus-gaz | 9-Camera de diluare a gazelor                                     |
| 5-Robinet cu sertar          | 10-Plasă de sârmă pentru uniformizarea Curentului de aer          |

Fig. 3 Local degassing installation

In the ejector structure, the following components are mainly included:

- funnel with hemispherical biasing (VENTURI type);
- the injection nozzle mounted on the compressed air supply rod;

- mounting case of Venturi funnel, with flange with circular duct and funnel centring disk;
- Rod mounting and guiding housing (buffer chamber) provided with a special flange for coaxial centring of the compressed air supply rods;
- special venting fan mounting bolt;
- the ejector connection to the gas suction side;
- Compressed air distributor for charging the ejector.

The ejectors used in the local degassing facilities at the mining units in the Jiu Valley have the following functional parameters:

- Nominal flow:  
 $Q_n = 6 \text{ m}^3/\text{min}$ , (3 DIV);  $Q_n = 10 \text{ m}^3/\text{min}$ , (5 DIV);  $Q_n = 18 \text{ m}^3/\text{min}$ , (8 DIV)
- Nominal depression:  
 $h_n = 250 \text{ mm Hg}$ , (3 DIV)  $h_n = 300 \text{ mm Hg}$ , (5 DIV)  $h_n = 350 \text{ mm Hg}$ , (8 DIV)
- Compressed air consumption: 4 - 10  $\text{m}^3/\text{min}$ ;
- Range of action: 2.000 m.

As methane dilution station (mixing chamber), it can be used:

- mine workings, divided by a sealed partition wall;
- ventilation tubes.

Methane dilution in the mixing chambers located in the mining works through a partition wall provides for the execution of the dilution on one side of the mine working, with the closure of the space at the ends with wire mesh. The process provides the conditions for dilution of methane flows ranging from 1 to 4  $\text{m}^3/\text{min}$  at concentrations up to 1.5% by volume of methane.

### 3. Conclusions

Analysing the results of the degassing specific parameters according to the type of rocks in the bed and the roof of the coal layers subjected to the degassing process leads to the following findings:

- E.M. Livezeni:
  - the average flow rate of captured gas was  $2.95 \text{ m}^3/\text{min}$  and the share of methane flow represented 55% ( $1.62 \text{ m}^3/\text{min}$ );
  - The average depression size created was 25 mm Hg at the drilling level and 35 mm Hg at the suction pipes in the exploited spaces;
  - the maximum methane concentration was 75% vol., Measured in the networks for the exploited space;
  - the rocks from the coalbed and of layer 3 roof, which was the subject of degassing, are of the type of clay, sandstone, muddy clay, marble sandstone and low greasy clay.
- E.M. Lupeni:
  - the average flow rate of captured gas was  $9.6 \text{ m}^3/\text{min}$  and the share of methane flow represented 67 % ( $6.05 \text{ m}^3/\text{min}$ );
  - The average depression size created was 68 mm Hg;
  - the maximum methane concentration was 100 % vol. in layer 3, bl. II, horiz.400;
  - the rocks from the coalbed and of layer 3 roof constitutes of sandy compact sandstone, limestone marble, claystone, claystone sandstone and quartz sandstone.

Exploitation mining	Average gas flow [ $\text{m}^3/\text{min}$ ]	CH <sub>4</sub> %	Volume CH <sub>4</sub> degage [ $\text{m}^3/\text{month}$ ]	Average flow CH <sub>4</sub> [ $\text{m}^3/\text{day}$ ]
Livezeni	2,15	61	56657	1715,7
Vulcan	1,5	86	55728	1879,5
Lupeni	3,5	66	99792	3397,5
Total central degassing stations Valea Jiului			212177	6994,7

By applying degassing to the Jiu Valley mines, taking into account the amount of methane evacuated through the ventilation system at the main ventilation stations, it resulted that through the degassing process, the total volume of methane evacuated (aeration and degassing) extracted by degassing, from:

- Lupeni Mine: 18,02 %;
- Vulcan Mine: 17,38 %;
- Livezeni Mine: 9,21 %.

## Acknowledgements

This paper was developed within the Nucleu-Programme, carried out with the support of Romanian Ministry of Research and Innovation, project no. PN 18 17 02 02, project title: Research on improving health and safety in hazardous environments with explosive, flammable and toxic atmospheres (in Romanian: Cercetări privind îmbunătățirea stării de securitate și sănătate în medii periculoase cu atmosfere explozive, inflamabile și toxice).

## References

- Băltărețu, F., Matei, I. – *Ghid practic pentru proiectarea și verificarea instalațiilor de aeraj parțial*, Ministerul Minelor, Petrolului și Geologiei, (1987).
- Băbuș, G., Moraru, R., ș.a., *Ingineria mediului și ventilația în subteran*, Editura Tehnică București, (2000).
- Ianc, N., *Reducerea impactului produs asupra mediului de gazul metan din minele de cărbuni din Valea Jiului*, Teza de doctorat, Universitatea din Petroșani, (2015).
- Lupu, C., *Metanul din minele de cărbune*, Editura INSEMEX, Petroșani, (2007).
- Tomescu, C., *Cercetări privind creșterea gradului de securitate în procesul recuperării și valorificării metanului din arealul carbonifer al Văii Jiului*, Teza de doctorat, Universitatea din Petroșani, (2015).

# Sensitivity analysis on major heat sources and evaluation of cooling systems to provide adequate work conditions in underground metal mines

Kocsis C. Karoly<sup>a\*</sup>, Roghanchi Pedram<sup>b</sup>, Teixeira B. Marcelo<sup>a</sup>, Parrish Jacob<sup>a</sup>,  
Scalise Kyle<sup>a</sup>

<sup>a</sup>Department of Mining and Metallurgical Engineering, University of Nevada, Reno, NV, USA.

<sup>b</sup>Department of Mineral Engineering, New Mexico Tech Institute of Mining and Technology, NM, USA.

---

## Abstract

In recent years, increasing consumption of goods led to the depletion of many shallow ore reserves in the USA and world-wide. Consequently, the underground mines are becoming deeper, hotter, and increasingly mechanized. An underground environment with high temperature and humidity conditions generated by various heat sources such as auto-compression, strata, and mining equipment can affect the thermoregulation processes of the human body. This can lead to a series of heat-related illnesses such as heat rash, heat cramps, heat exhaustion, and heat stroke. There are two methods used to control the climatic conditions in underground mines: (1) Using ventilation and cooling to reduce the thermal stress on the mine workers, and (2) Reducing the heat generated by major heat sources. The latter method could be achieved, for instance, by reducing the fleet size or using battery-powered/electric equipment, to reduce the heat generated by the mining equipment. In addition, understanding the heat transfer processes is also critical for the development of efficient cooling systems to ensure thermal comfort for the underground workforce. This in turn can increase productivity and reduce the risks of heat-related illnesses. To identify what sources generate the greatest amount of heat in the production stopes, efforts have been focused to develop bulk and/or localized cooling systems to provide adequate work conditions in underground mines. This paper aims to identify and analyze all major heat sources and their individual contribution to the overall heat load in underground mines. The effect of heat exposure on health, safety, and productivity of the mine workers will be summarized and discussed. Furthermore, a sensitivity analyses aiming to identify the most cost-effective ventilation strategies and cooling methods and systems based on specific geological and mine operating characteristics are discussed.

**Keywords:** climatic conditions, heat sources, heat exchange processes, mine ventilation, cooling systems, thermal comfort;

---

## 1. Introduction

The human body has certain mechanisms to maintain its core temperature at 37 °C with  $\pm 1^\circ\text{C}$ . The heat produced in the human body can be classified as: (1) environmental heat load, and (2) metabolic heat. The exchange of heat between the human body and the environment are in the forms of convection, conduction, and radiation. Besides these, heat is produced by internal metabolic processes and depends primarily on the level of activity (e.g. work rate). The muscular efficiency is in the range of 20-25%, at the best (Gravelling, Morris, and Graves, 1988). Consequently, a great proportion of remainder inefficiencies are transferred to the environment as heat.

Depending on the environmental parameters (air temperature, humidity, radiant temperature, barometric pressure), and the skin temperature, heat can be transferred from the environment to the body or vice-versa. In addition, heat is generated by the human body while activities are performed. The heat stored by the human body can be assessed by subtracting the heat losses from the heat gained. If the value is positive, the body's temperature increases and heat-related illnesses may occur. The ability to cope with a hot and humid environment varies from person to person. The individual factors influencing the risk of developing a heat-related illness are: body mass, physical fitness, acclimatization, obesity, and consumption of legal or illegal drugs (Payne & Mitra, 2008).

---

\*Kocsis C. Karoly.

E-mail address: kkocsis@unr.edu.



Experiments showed that if work is continuously performed in a comfortable climate, the core temperature of the human body will increase, and will reach an equilibrium level. The equilibrium level can be reached independent of the environment for air temperatures ranging from 5 to 30°C. However, later findings highlight that this temperature range varies inversely with the work rate. Above the upper limit of the range, the body will face a disequilibrium state, a situation in which heat will be stored in the human body, as its core temperature rapidly increases (Nielsen & Nielsen, 1962). These research findings have been the bases for limiting work in hot environments through the use of heat stress standards (Lind, 1963). From this point, the body utilizes two mechanisms to transfer heat to the environment: (1) increasing blood flow to vital organs, and (2) sweating.

The hotter the underground environment, the more uncomfortable and irritable workers can become and, given a working environment exceeding 42°C can even cause death (Torres, 2011).

## **2. Cooling Systems for Underground Metal Mines**

As the mines are getting deeper and hotter, a greater volume of air is needed to provide adequate work conditions. The approach ventilation-only, is always preferred, and is used for as long as possible in order to postpone the costs of introducing a refrigeration plant (Mackay, Bluhm, & Van Rensburg, 2010). However, at a certain depth, known as critical depth, no effectiveness will be reached just by delivering increased air volumes. At this point, a cooling system should be installed. When a cooling system is installed, the mine's intake air volume should be reduced in order to avoid escalating costs when cooling large volumes of air (Brake D. J., 2001).

There are four major cooling systems, which can be considered for underground metal mines: (1) surface bulk air cooling (BAC), (2) underground BAC, (3) spot cooling and, (4) micro-cooling (e.g. air-conditioned cabins). The cooling power provided by the refrigeration plant may be reduced if some energy efficient systems are implemented such as: (a) the use of an energy recovery system, (b) replacing diesel equipment with battery/electric equipment, and (c) using a ventilation-on-demand (VOD) control systems, which has the ability to provide variable air volumes to the production workings. The bulk air cooling (BAC) system uses chilled water or other refrigerant to exchange heat with the mine air. It can take place in a direct or indirect heat exchanger. The chilled water is provided by either a surface or underground refrigeration plant. A surface BAC system can be a feasible option due to practical aspects. Compared to underground cooling systems, the surface BAC systems are often cheaper and undemanding when it comes to installation, operation, and maintenance (Wilson, Bluhm, Funnell, & Smit, 2003). On the other hand, the surface BAC systems have a low positional efficiency when compared to other methods of cooling since the air is cooled far from the production workings, and as cooler the intake air more heat will be transferred from strata, as the mine air flows along the openings (Mackay, Bluhm, & Van Rensburg, 2010). Consequently, based on surface air temperature, the applied mining method, and other site-specific characteristics, an underground BAC system could be more economical.

An underground cooling system can be introduced by several techniques: (a) as chilled service water, (b) secondary air cooling, (c) tertiary air cooling, and (d) as controlled recirculation within established mine districts (Mackay, Bluhm, & Van Rensburg, 2010). A primary underground BAC system is usually installed not far from the bottom of the intake shaft. If the distance between the underground BAC to the work areas is significant, a secondary stage, or even a tertiary stage cooling system is considered. In respect to secondary air cooling, the components and the methods to cool the mine air are selected according to site-specific characteristics. One option is to use direct-contact spray heat exchangers, while the other option is to use closed-circuit cooling-coil heat exchanger banks. A controlled recirculation system may be used to increase airflow within hot areas. Tertiary or "in-stop" cooling can be achieved by means of tertiary air coolers, where chilled water is used as a coolant (Mackay, Bluhm, & Van Rensburg, 2010).

An ice-based cooling system becomes feasible when the cost of pumping water from underground to surface becomes extremely expensive. Therefore, ice-making plants can be considered to deliver ice to the production workings. Ice is usually mixed with water to form an ice slurry, it is then moved underground by means of gravity. The advantage of this process is that the heat added by auto-compression is used as latent heat to melt the ice, therefore, the slurry arrives underground ready to be used for BAC system or localized spot cooling systems (Bellas & Tassou, 2005).

Spot cooling also known as "decentralized" cooling and is used when heat issues are encountered in areas away from the main airways. The system consists of an evaporator installed inside the auxiliary duct and a condenser installed outside the duct (McPherson, 2012). A high positional efficiency and mobility can be achieved, as the system is close to the production stopes. The main disadvantage includes limited cooling capacity due to size constraints, and the ability of the system to reject heat into the mine's return airways (Brake D. J., 2001).

## **3. Major Heat Sources and Site-Specific Characteristics Affecting Work Conditions**

The total heat load in an underground mine comes from various sources. Depending on the amount of heat generated by each source relative to the mine's total heat load, a particular type of cooling system is preferred. In cases where the surface dry-bulb ( $T_d$ ) and wet-bulb ( $T_w$ ) temperatures are high, a surface or an underground BAC cooling system could be used. In this case, it is advised to install the BAC system underground in order to promote heat transfer from the ventilating air to strata, as the intake air downcasts the shaft. On the other hand, if the majority of the heat load comes

from internal sources such as mining equipment, backfill, groundwater, the most cost-effective cooling strategy is to utilize a localized cooling system (e.g. spot cooling).

The refrigeration turndown ratio refers to the usage of the cooling system throughout the year. A high ratio means that the system is only used during summer, while during spring, fall and winter the system is turned off (Brake D. J, 2002). To select an efficient cooling system many site-specific factors as well as operating characteristics need to be taken into account. The site-specific and environmental parameters influencing the decision on the type and location of a cooling system are (Brake D. J, 2002): (1) Auto-compression, (2) Geothermal gradient, (3) Surface climate, (4) Employed mining method, (5) Level of mechanization, (6) Mining depth.

### 3.1. Auto-compression

Auto-compression is the conversion of the potential energy into enthalpy when a fluid flows from a higher elevation to a lower elevation. For example, the dry-bulb temperature ( $T_d$ ) lapse rate can be in the range of  $9.7\text{ }^{\circ}\text{C}$  per 1,000 meters considering a dry shaft and 101.3 kPa of barometric pressure at the collar of the shaft. However, in the majority of cases, the shaft or the airways are not completely dry. Consequently, the rate of increase in the dry-bulb temperature ( $T_d$ ) is eroded by the cooling effect of evaporation (McPherson, 2009). In case of wet conditions down an intake shaft and along horizontal airways, the dry-bulb temperature ( $T_d$ ) will in fact decrease as a result of evaporation (Payne & Mitra, 2008). The wet-bulb temperature ( $T_w$ ) will increase as the intake air picks up moisture (Whillier & Ramsden, 1975). The variation of the dry-bulb temperature ( $T_d$ ) with the change in moisture content of the air is shown on Figure 1.

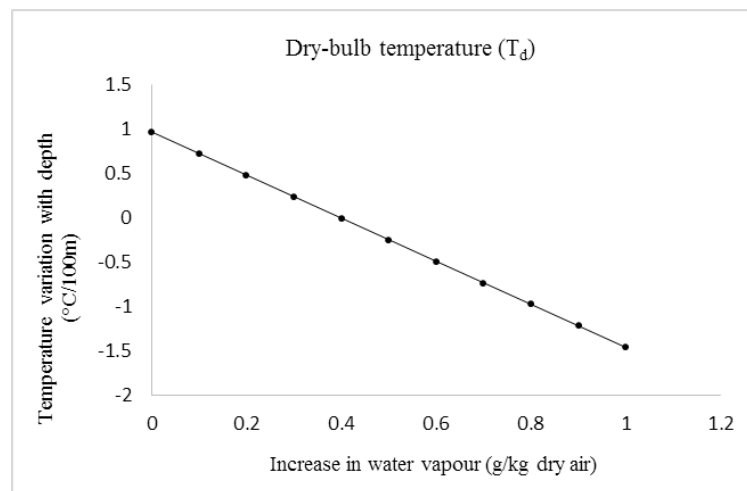


Fig. 1: The effect of moisture content on the dry-bulb temperature ( $T_d$ )

For underground mines located in Northern Ontario (Canada) and Australia, auto-compression can account for over 50% of the total heat load. However, at metal mines in western USA its significance can be considered as moderate, thus profoundly impacting the cooling system (Carpenter, Roghanchi, and Kocsis, 2015). Heat added to the mine air also depends on the elevation, gravity, and the specific heat of the air. Fig. 2 shows the effect of auto-compression as well as the effect of average surface air temperatures on the climatic conditions underground. The effect of auto-compression and surface air temperature have been analyzed for 3 different scenarios, which are presented in Table 1. The maximum allowable wet-bulb temperatures in the mine's return air were assumed as:  $28^{\circ}\text{C}$ ,  $27^{\circ}\text{C}$ , and  $26^{\circ}\text{C}$ . The adiabatic lapse rate on the wet-bulb temperature ( $T_w$ ) was assumed as  $4\text{ }^{\circ}\text{C}$  per 1,000 meters.

Table 1: Surface air temperatures for three scenarios

Scenario	Dr-bulbtemperature ( $^{\circ}\text{C}$ )	Relative Humidity (RH)	Wet-bulb temperature ( $^{\circ}\text{C}$ )
(1) Maximum daily average parameters during summer	32	51%	21
	28	43%	29
(2) Maximum average parameters during summer			
(3) Average parameters during summer	18	43%	11

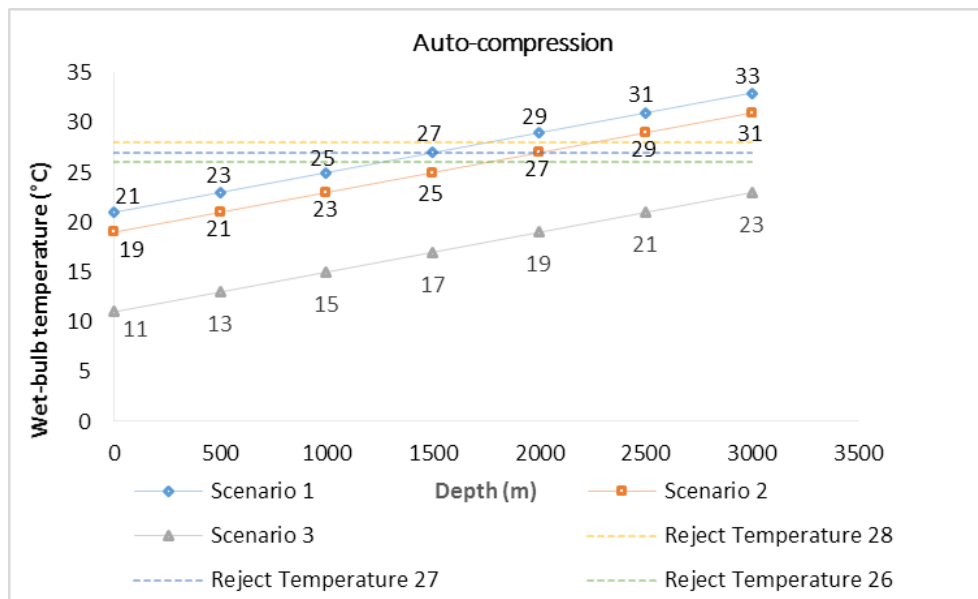


Fig. 2: The effect of auto-compression on the heat load

Figure 2 shows that the critical depth where a cooling system is required assuming that the wet-bulb temperature ( $T_w$ ) in a mine's return airways cannot exceed 28°C is 1,700 meters for Scenario 1, 2,250 meters for Scenario 2, and over 3,000 meters for Scenario 3. Furthermore, if the allowed wet-bulb temperature in the mine's return airways is lowered to 27 °C, the critical depth where a cooling system is required is 1,500 meters for Scenario 1, 2,000 meters for Scenario 2, and over 3,000 meters for Scenario 3. These parameters and values are also provided in Table 2.

Table 2: The critical depth

Allowed wet-bulb temperature (°C)	Surface wet-bulb temperature (°C)		
	Scenario 1	Scenario 2	Scenario 3
26	1,250 m	1,750 m	>3,000 m
27	1,500 m	2,000 m	>3,000 m
28	1,700 m	2,250 m	>3,000 m

### 3.2. Geothermal gradient

The geothermal gradient is the variation of the virgin rock temperature (VRT) as a function of depth, and it is also a function of the rock thermal properties (McPherson, 2012). The geothermal gradient controls the amount of heat, which is transferred from the surrounding rock formations into the mine air, and vice versa. If the airway is dry, the heat flow is basically proportional to the difference between the virgin rock temperature (VRT) and the air temperature (Payne & Mitra, 2008).

The virgin rock temperature (VRT) is increasing with depth. In general, at approximately 50 meters below surface the rock temperature remains equal to the average surface air temperature. Between 50 meters and 100 meters, the rock temperature changes due to circulating ground water. Below 100 meters, the rock temperature increases according to the geothermal gradient, and also depends on the thermal properties of the surrounding rock formations such as conductivity, diffusivity, as well as tectonic setting (Maurya, Kailash, Vardhan, Aruna, & Raj, 2015).

It is important to predict the virgin rock temperature (VRT) at deeper levels in order to quantify the heat which will be transferred from strata to the ventilating air. For example, a sensitivity analysis was carried out to determine the virgin rock temperature (VRT) as a function of mining depth considering that the surface rock temperature is 18 °C, while the geothermal gradient varies by 10 °C/km, 20 °C/km, 30 °C/km, and 40 °C/km. Based upon the sensitivity analysis, the virgin rock temperature (VRT) trends are presented in Figure 3.

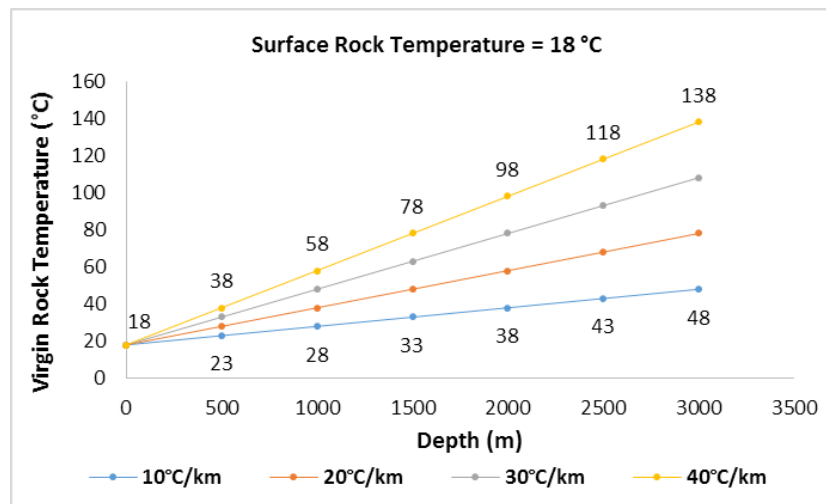


Fig. 3: Virgin rock temperature (VRT) variation as a function of depth

### 3.3. Surface climate

The surface air temperature has a significant impact in determining the cooling capacity of the refrigeration plant. As the intake air downcasts the shaft, the heat from auto-compression is also added to the ventilating air. At many underground mines, during summer the temperature of the intake air has a higher value than the shaft's wall. Consequently, the surface temperature needs to be carefully selected when developing a climatic model to determine the type and the cooling capacity of the refrigeration plant. For example, if the selected surface air temperature is 1°C higher than the correct value, the cooling capacity of the refrigeration plant may be over-estimated by 3 to 4 MW, for an intake air volume of 850 m<sup>3</sup>/s (Karsten & Mackay, 2012). Thus, the added capital and operating costs over the life of the mine can be significant.

In a case study where all major heat sources were assessed and analyzed, the yearly average surface air temperature for an underground mine in Australia and an underground mine in South Africa was determined at 28 °C, and 18 °C, respectively. The difference was basically due to an altitude difference of 1,400 meters between the two mines (Brake D., 2002). For elevated average surface air temperatures such as the mine in Australia, it may be wise to consider installing a high capacity BAC cooling system on surface, as these type of cooling systems are easy to install and to maintain when compared to an underground BAC system. Operational experience has shown that within the development headings and throughout the production workings heat becomes a problem for the mine workers when the average surface wet-bulb temperature ( $T_w$ ) exceeds 21°C (De Souza, 2002). Figure 4 shows the average surface dry-bulb temperature ( $T_d$ ) of the air during 2016 in the Elko and Winnemucca areas. Although the yearly average surface air temperature is relatively low for both areas, in July the average dry-bulb temperature has increased to 21.25°C in Elko and 22.5°C in Winnemucca. This means that during the month of July, the maximum dry-bulb temperature on surface can reach temperatures in the range of 40 °C.

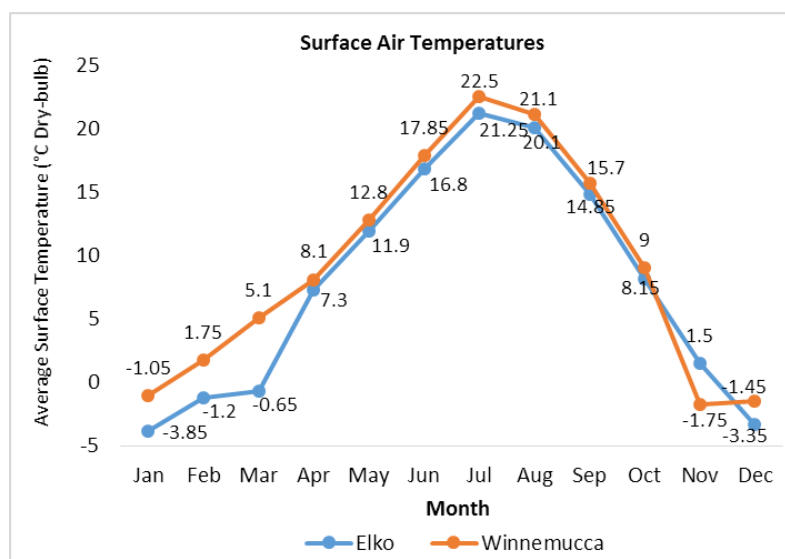


Fig. 4: Average surface air temperature variation in Elko and Winnemucca areas, Nevada.

### 3.4. Employed mining method

The ventilation system of a mine, as well as its cooling system can largely depend on the mining method employed. For example, when the “sub-level stoping” method is employed, efficient airflow distribution to the work areas and throughout the mine can be a difficult assignment. As the ventilating leaks into the caved areas and voids, the heat removal capacity of the ventilation system can be significantly compromised (Guney & Bell, 1979).

An underground mine’s layout can largely depend on geological factors, geotechnical characteristics, and the geometry of the orebody. For example, vein type deposits are usually mined by means of selective mining methods such as the “cut-and-fill” mining method, and while the mine can be relatively deep, the development and production stopes are not spread laterally. Thus, the residence time of the intake air from the collar of the shaft to the production workings is not significant. Consequently, less heat may be transferred from strata to the ventilating air. Conversely, in case of massive and tabular ore deposits the development and production workings are spread out, thus allowing the ventilating air to pick up a large amount of heat from strata, mining equipment and from other sources (Brake D., 2002). In this case, a spot cooling system is more effective than a surface BAC system. When the “block caving” mining method is employed, a large amount of broken ore is released. Consequently, the heat transferred to the ventilating air from the broken ore and mining equipment can be significant. For example, a study performed at a copper mine where the “block caving” method was employed highlighted that the heat transferred to the mine air from the broken ore was in the range of 30 MW, which accounted for approximately 21% of the total cooling capacity of the mine (Bluhm, Moreby, von Glehn, & Pascoe, 2014).

The employed mining method can also affect ground water inflow into the mine through fissures, as heat can be transferred to the mine air from this source as well.

### 3.5. Level of mechanization

The mining equipment utilized in underground metal mines is either diesel and/or electric. The level of mechanization can dictate the heat load in underground mines, and consequently aids in choosing an appropriate cooling method. However, in mechanized metal mines there is low service water usage mainly because in this mines the drilling process is fully mechanized or even automated, and hand-held drills, which are responsible for the majority use of service water usage are no longer used (Brake and Fulker, 2000).

Diesel-powered equipment such as LHDs, haul trucks, and drills generate a large amount of heat and contaminants such as diesel particulate matter (DPM) as well as combustion gases (Roghanchi & Kocsis, 2017). The heat released depend on the duty cycle of the mining equipment and on the engine’s efficiency, which at peak power is considered to be at 33%. Thus, approximately two-thirds of the total input power is released into the mine air as heat (McPherson, 2012). Battery-powered and electrical equipment have a higher efficiency than diesel equipment resulting in less heat released in the production workings and along the haulage drifts. This higher efficiency is achieved because the electric motor requires less input power than diesel engines for the same performance due to torque characteristics of the former (Millar, Trapani, & Romero, 2016). For battery-bowered and electrical equipment the total heat produced is the rate at which power is supplied, less any work done against gravity. Furthermore, the efficiency of the equipment determines the distribution of heat produced. Diesel equipment will produce approximately three times as much heat as battery-powered equipment of the same mechanical output. Another important difference between diesel and battery-powered equipment is that diesels produce part of their heat output in form of latent heat, as each liter of diesel fuel that is consumed produces approximately 1.1 liter of water in the exhaust gases. In situ tests have shown that the factor can actually vary from 3 to 10 liters of water per liter of fuel consumed due to evaporation of water from cooling systems and where water is employed to control dust concentrations (McPherson, 2012). In respect to heat generation, a comparison was performed in an underground mine in Northern Ontario, Canada between a diesel and electric LHD. The results are provided in Table 3 (Millar, Trapani, & Romero, 2016).

Table 3: Heat generation from diesel LHD versus electric LHD

Parameters	Diesel LHD	Electric LHD
Engine output	243	177
Thermal efficiency (%)	37	95
Heat dissipated from the powerhouse (kW)	516	9
Drive train losses (kW)	97.2	97.2
Total heat dissipation (kW)	614	107

#### 4. Discussion

In many instances, simply adjusting or upgrading the auxiliary ventilation system in a problem area of a mine will effectively dilute the pollutants that are generated during production operations and provide adequate climatic conditions for mine workers. Methods to achieve this include (1) extending the auxiliary duct toward the face, (2) installing an additional auxiliary fan to overcome the added pressure losses in the system, (3) changing the size of the fan, (4) switching from an exhausting arrangement to a forcing arrangement, and (5) installing an overlap auxiliary ventilation system. If the required air volumes in the active areas are more than the primary ventilation system can provide, other measures may need to be considered in order to increase airflow delivery. This may include the installation of a ventilation-on-demand (VOD) control system, adding booster fans to improve airflow distribution, and upgrading the surface fans.

Understanding the heat sources and the heat exchange processes in underground mines is critical to design and install effective ventilation and cooling systems in order to provide adequate work conditions in the development and production stopes. To assure appropriate work conditions in underground mines, a “human comfort model” was developed at the Mining and Metallurgical Engineering Department of the University of Nevada, Reno (UNR) as part of a 5-year research study. For an underground worker, this comfort model has the ability to determine the following parameters and work conditions: (1) Maximum allowable dry-bulb temperature ( $T_d$ ), wet-bulb temperature ( $T_w$ ), and relative humidity (RH) in a production stope and throughout the mine as a function of air volume ( $Q$ ) and work intensity (e.g. metabolic rate), (2) Continuous work and rest periods in the production areas while minimizing heat stress due to dehydration and adverse work conditions, (3) Optimum airflow velocity in order to assure thermal comfort in the production workings and throughout the mine, (4) Ventilation and climatic parameters for maximum thermal comfort as a function of activity level and clothing. Climatic simulations performed on the “human comfort model” showed that the relative humidity (RH) contributes a lot more to deviations from thermal comfort than any other climatic parameters. It is flowered by the level of activity (e.g. metabolic rate) and airflow velocity ( $v$ ). Quantifying the amount of heat generated from major heat sources such as auto-compression, strata, and mining equipment are critical to design efficient ventilation and cooling systems in order to assure adequate work conditions as a function of mining depth and the level of mechanization.

A number of cooling systems and strategies are available, with varying cooling capability, cost, mobility and efficiency. No one solution is better than the other, as mine specific conditions may require a cooling method that is unique to the particular operation. The majority of the most widespread cooling methods as well as some of the less common ones are basically applicable to the hot and humid underground mines in United States. Cooling systems can be upgraded, and different combinations of cooling systems can be used underground. This is important not only for the safety and health of the mine workers but also for the sustainability of the mining industry world-wide.

#### References

- Bellas, I., & Tassou, S. A., *Present and future application of ice slurries*, International Journal of Refrigeration, 28(1), 115-121, (2005).
- Beshir, M. Y., & Ramsey, J. D., *Heat stress indices: A review paper*, International Journal of Industrial Ergonomics, 89-102, (1988).
- Biffi, M., & Stanton, D. J., *Cooling power for a new age*. 3<sup>rd</sup> International Platinum Conference "Platinum in Transformation", The Southern African Institute of Mining and Metallurgy, (pp. 239-247), (2008).
- Bossard, F. C., *Calculating underground mine air-cooling requirements*, Proceedings of the 6th US Mine Ventilation Symposium, Salt Lake, UT, USA, (p. (Vol.2123)), (1993).
- Brake, D., *Design of the world's largest bulk air cooler for the Enterprise mine in Northern Australia*, Proceedings of the North American/Ninth US Mine Ventilation Symposium, (pp. 381-390), (2002).
- Brake, D. J., *The application of refrigeration in mechanized mines*, Australasian Institute of Mining and Metallurgy, (pp. Vol. 306, No. 1, pp. 1-10), Parkville, (2001).
- Brake, D. J., & Fulker, R., *The ventilation and refrigeration design for Australia's deepest and hottest underground operation*. The Enterprise mine. Proc MassMin, (pp. 611-621), (2000).
- Brake, D. J., Donoghue, M. D., & Bates, G. P., *A new generation of health and safety protocols for working heat*. Proceedings of the 1998 Queensland Mining Industry Occupational Health and Safety Conference, (pp. 91-100), (1998).
- Carpenter, K. E., Roghanchi, P., and Kocsis, K. C., *Investigating the importance of climatic monitoring and modeling in deep and hot US underground mine*, Proceedings of 15th North American Mine Ventilation Symposium, Virginia Tech, Virginia, (pp. 1-4), (2015).
- Consultants, A., *Basic Mine Ventilation*, AMC Consultants, (2005).
- De Souza, E., *Mine Ventilation*, Proceedings of the North American/Ninth US Mine Ventilation Symposium, Kingston, Canada, CRC Press, (2002).

- Derrington, A. S., *Will Your Mine Require Cooling? 12<sup>th</sup> AUSIMM operator's conference*, Adelaide, SA, (2014).
- Fanger, P. O., *Thermal comfort: Analysis and application in environmental engineering*, Copenhagen: Danish Technical Press, McGraw-Hill, (1970).
- Government of New South Wales, Australia, *Work Health and Safety (Mines) Regulation 2014*, New South Wales, Australia, (2014).
- Government of South Africa, *Mining Safety Laws*, Retrieved from [www.miningsafety.co.za](http://www.miningsafety.co.za), (2017, October 10).
- Government of South Africa, *Mining Safety*, Retrieved from [www.miningsafety.co.za](http://www.miningsafety.co.za).
- Gravelling, R. A., Morris, L. A., & Graves, R. J., *Working in hot conditions in mining: a literature review*, Institute of Occupational Medicine, (1988).
- Guney, M., & Bell, A. R., *Ventilation and refrigeration practices together with environmental thermal problems at the Mindola mine, Zambia*, CIM BULLETIN, 72(801), (pp. 63-69), (1979).
- Hartman, H. L., Mutmansky, J. M., Ramani, R. V., & Wang, Y. J., *Mine ventilation and air conditioning*, John Wiley & Sons, (1997).
- Health Safety Training, *Heat stress monitoring*, Retrieved from OHSA Services, (2017, October 10).
- Howes, M., *The design and control of mine refrigeration systems*, Doctoral dissertation, University of Nottingham, (1992).
- Jacklitsch, B., Williams, W. J., Kristin, M., Coca, A., Kim, J. H., & Turner, N., Occupational exposure to heat and hot environments: revised criteria (2016).
- Karsten, M., & Mackay, L., *Underground environmental challenges in deep platinum mining and some suggested solutions. Platinum 2012, 5th International Platinum Conference-'A Catalyst for Change'*, Johannesburg: Southern African Institute of Mining and Metallurgy, (2012).
- Kjellstrom, T., Lemke, B., Hyatt, O., & Otto, M., *Climate change and occupational health: A South African perspective*, SAMJ: South African Medical Journal, 104(8), 586-587, (2014).
- Lind, A. R., *A physiological criterion for setting thermal environmental limits for everyday work*, Applied Physiology, 51-56, (1963).
- Mackay, L., Bluhm, S., & Van Rensburg, J., *Refrigeration and cooling concepts for ultra-deep platinum*, The Southern African Institute of Mining and Metallurgy, (2010).
- Maurya, T., Kailash, K., Vardhan, H., Aruna, M., and Raj, M. G., *Potential Sources of Heat in Underground Mines - A Review*, Procedia Earth and Planetary Science, 463-468, (2015).
- McPherson, M. J., *Subsurface ventilation and environmental engineering*, Springer Science & Business Media, (2012).
- Millar, D., Trapani, K., and Romero, A., *Deep mine cooling, a case for Northern Ontario*, Part I. International Journal of Mining Science and Technology, 26(4), 721-727, (2016).
- National Weather Service - United State, National Weather Service Forecast Office. (2017, November 10).
- Nielsen, B., & Nielsen, M., Body temperature during work at different environmental temperatures. Acta Physiologica, 56(20), 120-129, (1962).
- Nixon, C. A., Gillies, A. D., and Howes, M. J., *Analysis of Heat Sources in a Large Mechanized Development*, Proc. Fifth International Mine Ventilation Congress, (p. 109), (1992).
- Payne, T., & Mitra, R., *A review of heat issues in underground metalliferous mines*, Proceedings 12th US/North American Mine Ventilation Symposium, (pp. 197-201), (2008).
- Rawlings, C., and Phillips, H., Underground mine ventilation planning and design with regards to heat load and cooling mechanisms. In 8<sup>th</sup> International Mine ventilation Congress. Brisbane, Australia, (2005).
- Resources, D. O., Management and Prevention of Heat Stress, (1997).
- Roghanchi, P., Managing and Controlling the Thermal Environment in Underground Metal Mines. University of Nevada, Reno, Reno, USA, (2017, August).
- Roghanchi, P., and Kocsis, K. C., Challenges in Selecting an Appropriate Heat Stress Index to Protect Workers in Hot and Humid Underground Mines. Safety and Health at Work Journal, (2017).
- Whillier, A., and Ramsden, R., Sources of heat in deep mines and the use of mine service water for cooling. Proceedings of the International Mine Ventilation Congress, 339-346, (1975).



# Challenges and opportunities of underground coal mining in North-Eastern Hungary

Molnár József<sup>a\*</sup>, Debreczeni Ákosa<sup>a</sup>, Tompa Richárd<sup>a</sup>

<sup>a</sup>*Institution of Mining and Geotechnical Engineering, H-3515 Miskolc-Egyetemváros, Hungary*

---

## Abstract

Several decades of underground coal mines were in operation in the mountainous north-eastern part of Hungary. The main area of utilization of the mined out coal beside power generation was supplying households with fuel mostly for heating. In the beginning of the 1990ies the power plants in question were shut down for economic, environmental and technical reasons. Consequently all the mines were closed no later than 2004 and thousands of miners lost their jobs. A new perspective of coal mining can be enabled by other ways of utilization of coal, e.g. coal chemistry, etc. New opportunities of sustainable underground coal mining in the north-eastern part of Hungary are discussed in the paper. Safe and modern equipment and technology enabling high output, clean coal, furthermore high rate of yield are targeted. Analysis of the properties of coal deposits using three-dimensional (3D) modelling are used for considering opportunities of new mining operations.

*Keywords:* Underground mining, sustainability, clean coal, coal;

---

## 1. Introduction

Underground coal mines of north-eastern Hungary were the major source of fuel for household heating during the past decades until the mid-1990ies in Hungary. Beside household utilization it was used for power generation, industrial heating, chemical raw materials, etc. The highest annual output of the Borsod Coal Mines company estimated 4-5 million tons. Numerous mines of higher and less output could be found throughout the northwest and northern vicinity of the Bükk mountains near Miskolc, Sajószentpéter, Kazincbarcika, Edelény, Putnok, Ózd and Borsodnádásd.

Modernization of underground coal mining resulted mechanization of the work, automation, significant increase of output and consequently decrease of the number of longwalls in the 1960-1980ies. Only 12 longwalls were in operation by the 1980ies (Molnár 2016). As a result of changes in political and economic conditions all the underground operations were shut down by 2004.

## 2. Cadastre of Hungarian coal reserves

Significant coal reserves remained in Hungary despite mine closures, and these could be taken into account when considering future fuel and raw material demand of the country. So Mining and Geological Survey of Hungary (MBFSZ) contributed a new cadastre of Hungarian coal deposits of greater or less reserves throughout the country which is available in electronic digital form ([https://map.mbfisz.gov.hu/coal\\_cadastre/](https://map.mbfisz.gov.hu/coal_cadastre/)). Geological information that can be obtained using the database in question is of essential importance in mine design.

## 3. Demand for new brown coal sources

A special research took place in the past years analyzing possibility of establishing coal chemical industry in the Borsod region in question especially for methanol production. So reserves of brown coal were taken into consideration such as near Kazincbarcika (Tardona), Edelény (Szendrő), and Putnok (Dubicsány and Sajómercsé II). Coal demand of chemical utilization should be considered a lucky situation from mining point of view. On the one hand such a plant needs coal of constant quantity and quality as raw material and on the other hand opening a new mine of economic

---

\*Molnár József. Tel.: +03-646-565-111.  
E-mail address: bgtmj@uni-miskolc.hu.

output requires one or more major industrial consumers. Chemical industry which has similar remarkable traditions in the region as mining can be the only major buyer as utilization of coal for power generation is not preferred this time.

There are several brown coal deposits in the Borsod region, we focus on the Dubicsány and Sajómercse II ones.

Both coal deposits are close the Sajó river at town of Putnok. Sajómercse II consists of the eastern remains of the former Putnok underground coal mine south of Sajó furthermore some 10 million tons of east of it. The Dubicsány deposit which is north of the river is totally untouched as no production operations were in it in the past.

Main properties of mining point of view of both deposits are described in the paper published by MBFSZ (Debreczeni et al. 2018). Institution of Mining and Geotechnical Engineering was participant in preparing mining plans.

#### 4. The Dubicsány brown coal deposit

262 boreholes were sunk on the 23.58 km<sup>2</sup> area of the Dubicsány brown coal deposit. Both core sampling and geophysical analysis were done for the vast majority of the holes. Two coal seams (IV and V) are available. Seam IV is thin, not mineable and can be found only on a small part of the deposit. Seam V is mineable and can be found on the whole area.

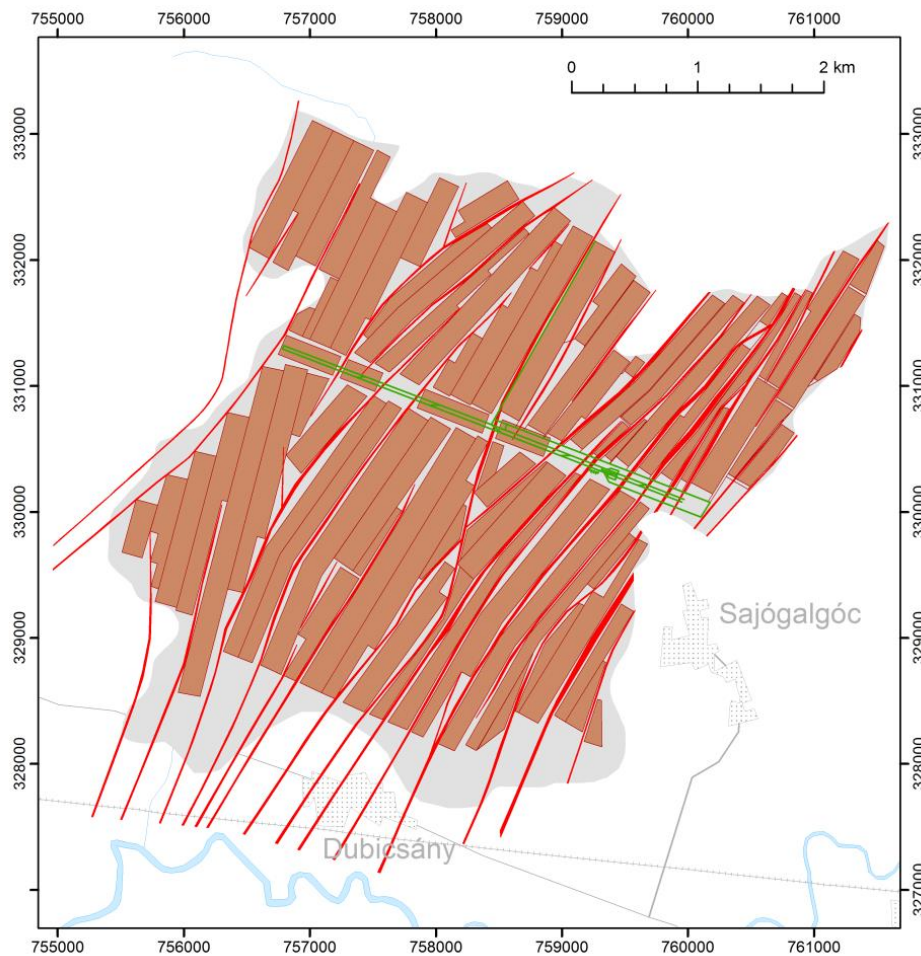


Fig. 1. Development of the Dubicsány coal mine and extraction of the coal reserve. Faults are highlighted by red lines. Püspöki (editor-in-chief), 2018

Total thickness of layers between the two seams (mostly sand) is of 70-72 m at average. Coal reserve of the Dubicsány deposit is concentrated in Seam V. Its thickness is 5-6 m on the vast majority of the deposit except on the south-western part and near the border of the seam. Thinner parts can be observed only on the southwest area as the lower part of the seam is of rather poor quality. Upper part of the seam is of higher sulfur content furthermore of higher calorific value due to lower ash content. The lower layer of the seam is of lower sulfur content and calorific value, this latter one as a result of higher ash content. Lower calorific values can be observed for greater seam thickness.

According to recent technical standards and mining plans, upper part of the coal seam is worth mine out using underground methods. Height of the coal face in the longwalls is 2.5-3.5 m, depth of the seam is 120-230 m on the northern and 200-300 m at the southern part of the deposit, thickness, mineable reserve estimates 49.9 million tons of 12,3 MJ/kg calorific value. The coal can be used as raw material for the chemical industry. Development of a new mine was planned by Borsod Coal Mines company, so two inclined shafts were sunk and more than 2000 m long drifts were made for exploration purposes beside drilling boreholes in the 1980ies. These old drifts should be replaced by new establishments.

The mine should be opened by two inclined shafts at the east side and a pair of main drifts from east to west as it was planned in the 1980ies (Fig. 1). Later a new ventilation shaft or borehole will be necessary to enable proper ventilation. Planned output of the mine amounts 1.54 million tons per year. Mine construction takes 4.5 years. Output will be increased to the total output in 5 years plus time required by design and obtaining licenses. Mine is planned to operate 37 years at the annual 1.54 million tons output level. Number of employees is estimated 900 not including number of personnel of suppliers.

The main mine hazard to be expected is due to water contained in aggregates of the roof layers. Dewatering is planned by wells drilled from the surface and established in the hanging wall of the drifts. Quantity of water can be expected 12-14 m<sup>3</sup>/min during the mine construction and later 6-9 m<sup>3</sup>/min. Water can be utilized in water supply of the region and/or industrial water in chemical industry utilizing coal. Mining operation does not risk drinking water reserves.

Environmental impact of an underground mine is much less than of a surface operation. Significant part of the inhabitants of the settlements of the region was employed by coal mining so favorable reception of a new mine can be expected.

## 5. The Sajómercse II brown coal deposit

The Sajómercse II deposit of 13.6 km<sup>2</sup> area consist of the remaining eastern part of the former Putnok underground coal mine and the coal reserves east of it. Geological exploration was based both on boreholes, using core sampling and geophysical methods as well and summarizing experiences obtained in the Putnok Mine.

The coal bearing strata contain 6 seams (low and high Borsod strips, seams I, II, III and III/a). Total thickness of these strata estimates 110 m, average depth is 270 m. The coal strips do not belong to the industrial reserve. Similarly Seam III/a under Seam III does not worth for utilization too due to its low quality (8000 kJ/kg calorific value) and irregular spread. Properties of the three main seams can be read in Table 1. The coal from these seams can be used as raw material for the chemical industry.

Table 1. Properties of coal seams of the Sajómercse II brown coal deposit

	seam thickness [m]	height of coal faces of longwalls [m]	coal reserve that can be extracted by longwalls [million tons]	average calorific value of coal that can be extracted by longwalls [kJ/kg]
Seam I	0,8-2,45	1,8-2,2 (average: 2,00)	5,289	12650
Seam II	0,7-5,65	2-2,5 (average: 2,25)	16,366	12000
Seam III	0,8-6,2	2,5-3,5 (average: 3,00)	15,974	13500
total			37,629	12728

Uniaxial strength of Seams I and II is of 12-24 MPa. A little bit lower strength (8-18 MPa) can be observed in Seam III due to clay layers in it. Country rocks are mostly low strength water-bearing layers consisting mostly of sand and clay. Highest strength was observed in the covering rocks of Seam III which is favorable for main drifts. Water hazard furthermore mud intrusion should be expected in all seams from the hanging wall and the foot wall too. Dewatering plans must take it into account.

Development of the Sajómercse II coal mine and extraction of the coal reserve of Seam II are shown on Fig. 2. Development system consist of a pair of inclined shafts on the northern side of the seams, a pair of main drifts in seam III as its country rocks are of higher strength and finally a ventilation shaft or borehole on the south.

Planned output of the mine amounts 1.0 million tons per year. Mine construction takes 3 years. Output will be increased to the total output in 4 years plus time required by design and obtaining licenses. Mine is planned to operate 37 years at the output level. Number of employees is estimated 600 plus number of personnel of suppliers.

The main mine is endangered by water hazard. Dewatering is planned by wells drilled from the surface and established in the hanging wall of the drifts. A detailed hydrogeological exploration is needed before starting mining operations. Quantity of water can be expected 6 m<sup>3</sup>/min according to experiences from Putnok Mine. Water can be utilized in water supply of the region and/or industrial water in chemical industry utilizing coal. Mining operation does not risk drinking water reserves.



Fig. 2. Development of the Sajómercse II coal mine and extraction of the coal reserve. Faults are highlighted by red lines. Püspöki (editor-in-chief) 2018

The mining area is close to the Lázberc Protected Area, consequently a complex sensitivity analysis is extremely important. Environmental impact of an underground mine is much less than of a surface operation. Significant part of the inhabitants of the settlements of the region was employed by coal mining so favorable reception of a new mine can be expected.

## 6. Surface facilities and infrastructure of the two mines

[1] Infrastructure required by a new mine is available in the region. There are arterials and main railroad in the valley of Sajó, local roads from the arterial, pipeline of potable water for the supply of the neighboring villages and electric distribution centers.

Former mining facilities do not exist that can be available. So new industrial roads power supply from two independent sources, water supply and sewage and mine water drainage should be built. Furthermore new coal transportation equipment is needed. This will be able to be designed when location and method of the utilization will be known. Proper mine waste disposal site should be established.

New buildings are required by the inclined shafts and the fan furthermore new silos, maintenance facilities, a storage partly covered by shelter, transformers, compressors, boiler, bath, dressing room, lamp house, dispatcher center, office, parking place, internal road and railroad network, public utilities and guarding facilities.



### 7. 3D modeling of Seam V of the Dubicsány deposit to enable more accurate estimations for mine design

A 3D model was developed to make mining plans more accurate. This model consisted of the following elements.

- Calorific value of the coal was determined as a function of different coal quality parameters (moisture, ash, volatile, fix carbon, sulfur, hydrogen content and higher calorific value). Univariate functions were obtained by regression method. Numbers of points used for the estimations were very high (5648-5989). Estimations proved to be accurate as coefficients of determination were fairly high  $0,7670 < R^2 < 0,9948$  and estimated errors of calorific value were low of  $0,335 \text{ MJ} \cdot \text{kg}^{-1} < D(\Delta F) < 2,248 \text{ MJ} \cdot \text{kg}^{-1}$ .
- Based on the geological data of the deposit a three-dimensional (3D) model was prepared for the numerical computations to determine the quantity and the quality properties of the coal. A picture based on the block model highlights the calorific value of the coal on the upper surface of Seam V (Figure 3). Resolution of the model is shown by the sizes of the blocks that are obvious on the figure.

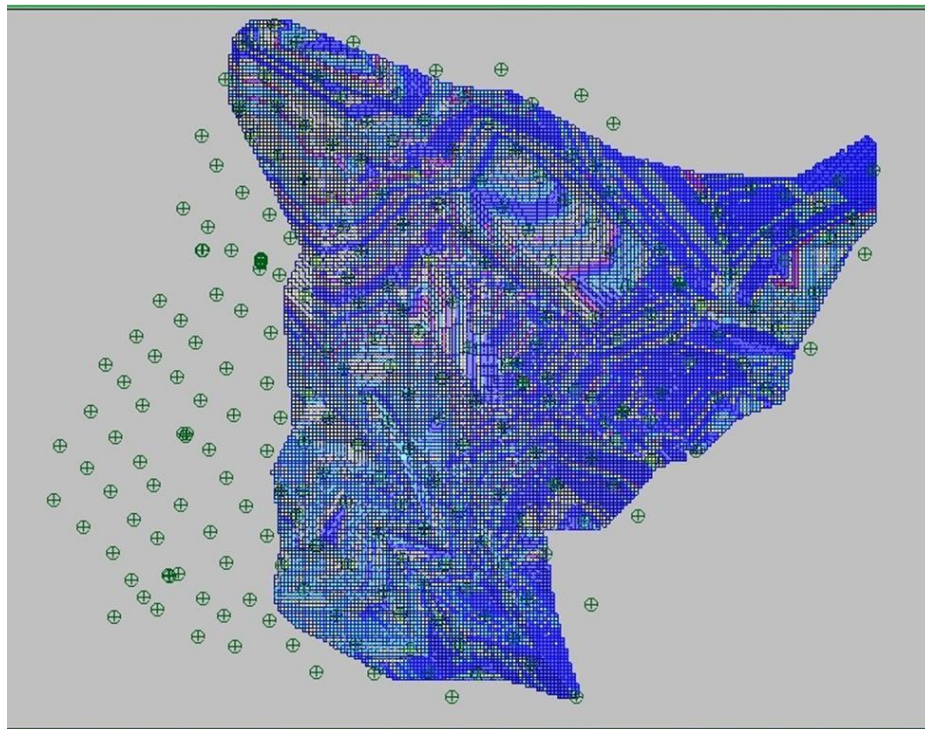


Fig. 3. 3D block model of calorific value of Seam V of the Dubicsány deposit. Drawn by Tompa R., 2018

- Thickness and mean calorific value of Seam V was determined for all boreholes throughout the whole deposit. Valuating thickness and specific heat content enabled more accurate determination of the borders of the parts of the mine (as shown fields North I, North II, South I and South II on Figure 4). Steadier seam thickness and calorific value in a mine field is more advantageous from mining engineering point of view.
- As coal quality changes (deteriorate) obviously from the covering layer of Seam V downwards, it is an extremely important question to determine the proper height of the coal face of the longwalls. This is important for the correct selection of the longwall equipment thus enabling selective cutting. A numerical analysis was done to find the distribution functions of the mass and the heat content furthermore the mean calorific value of the coal as a function of coal face height for the four parts of the mine. Future owners will be able to use these result for proper decisions in mine valuation and mining engineering design.

### Acknowledgements

The described work/article was carried out as part of the „Sustainable Raw Material Management Thematic Network – RING 2017”, EFOP-3.6.2-16-2017-00010 project in the framework of the Széchenyi2020 Program. The realization of this project is supported by the European Union, co-financed by the European Social Fund.

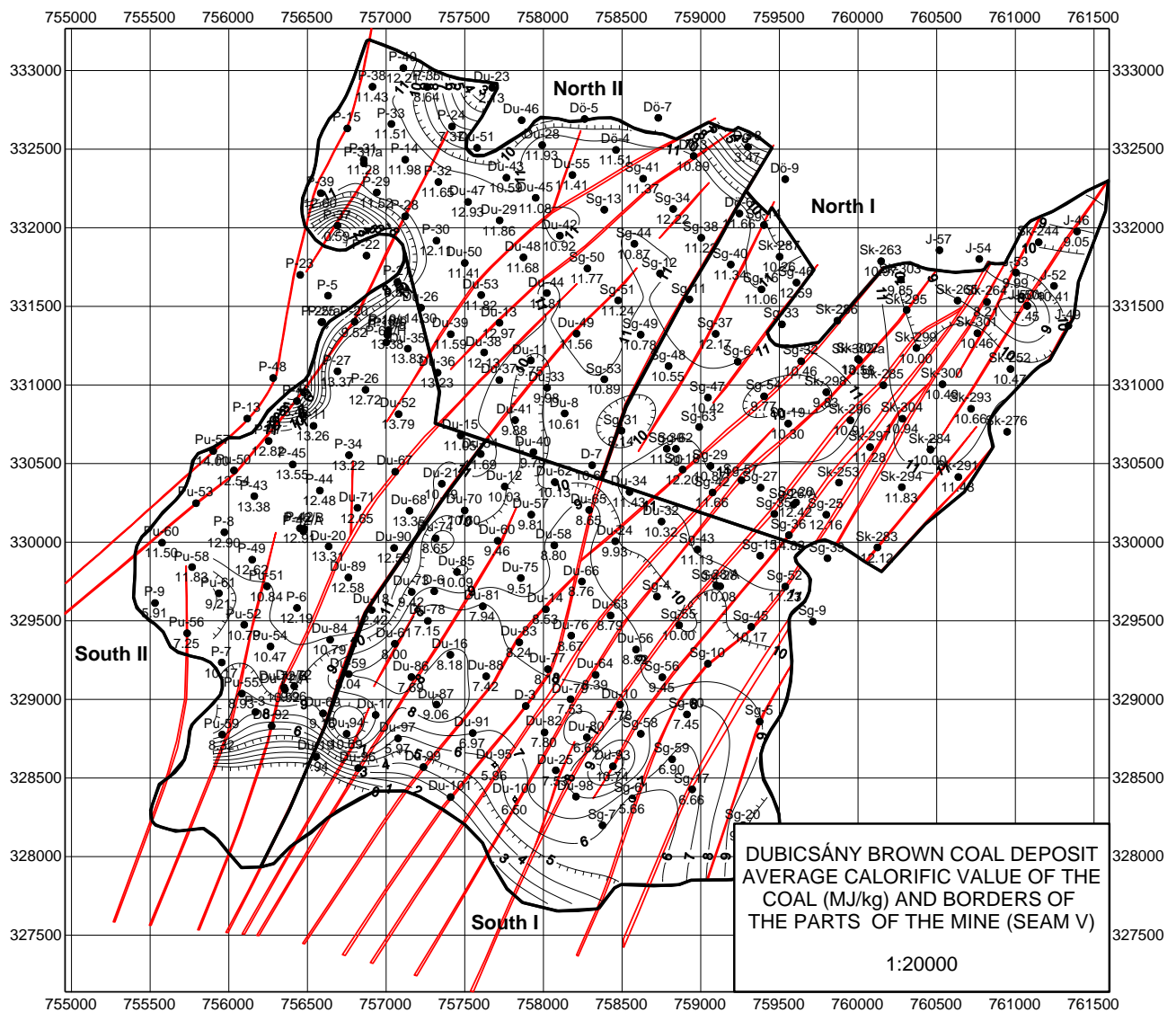


Fig. 4. Average calorific value of the coal (MJ/kg) and borders of the parts of the Dubicsány mine. Faults are highlighted by red lines. Molnár (editor-in-chief), 2018

## References

- Darling, P., (editor), *SME Mining Engineering Handbook*, Society of the Mining, Metallurgical and Mineral Exploration.
- Debreczeni, Á., Havelda, T., Bombicz, J., Kaufmann, T., Verböci, J., Bariczayné Szeiler, Z., *Kiemelt mélyművelésű szénbányászati projektek földtani bányászati adottságai*. In Püspöki Z. (editor-in-chief), *A hazai szénvagyon és hasznosítási lehetőségei*. Magyar Bányászati és Földtani Szolgálat, Budapest, pp. 85-146 (2018).
- Molnár J. (editor), *A dubicsányi barnakőszén előfordulás geometriai és minőségi adottságainak háromdimenziós modellezése, a gazdaságosan kitermelhető vagyon mennyiségének és minőségének újraértékelése*, Kutatási jelentés, Miskolci Egyetem, Bányászati és Geotechnikai Intézet, Miskolc (2018).
- Molnár, J., Tompa, R., *Some questions of mine safety of small mines in Hungary*. In 7<sup>th</sup> International Multidisciplinary Scientific Symposium – Universitaria SIMPRO 2016, 14-15 October, 2016, Petrosany, pp. 445-450. URL: <https://www.upet.ro/simpro/2016/downloads/Proceedings%20SIMPRO%202016.pdf>, Downloaded August 27<sup>th</sup>, (2016).
- Püspöki Z. (editor-in-chief), *A hazai szénvagyon és hasznosítási lehetőségei*, Magyar Bányászati és Földtani Szolgálat, Budapest (2018).

## Probabilistic approaches in tunnel design

Madear Gelu<sup>a\*</sup>, Madear Camelia<sup>b</sup>

<sup>a</sup> GOLDER, 1, South Parade, Doncaster, DN1 2DY, UK

<sup>b</sup> ECO-ROCCA Engineering SRL, 23, Parcului Street, Petritu - 335800, Romania

---

### Abstract

Usually, tunnel final linings are designed according to specific criteria and safety levels required by various codes – Eurocodes for projects located within EU. These codes are mainly applicable in conventional structures, where variability is extremely reduced, and a deterministic approach is largely used.

On the contrary, the loads on the final lining of tunnels result from the interaction of the rockmass, temporary support and the final lining. These loads are subjected to a higher degree of uncertainty due to the high variability of the geomechanical parameters of the rockmass.

On the other hand, materials used for the lining (shotcrete, concrete, steel), present a higher variability than similar materials used in surface construction, due to non-uniformities during the underground construction process. This paper investigates the variation of the final lining loads using Monte Carlo simulations performing a probabilistic analysis using Rocscience's RS2 Finite Element Software. Selection and validation of the Probability Density Functions (PDFs) for the input parameters is realised using @RISK add-on to Excel program.

*Keywords:* tunnel design, probabilistic approach, Monte Carlo simulations, FEM, uncertainty, PDFs;

---

### 1. Introduction

The considerable uncertainty of the geomechanical parameters has led to conservative designs of tunnel linings with “hidden” safety factors (i.e. the empirical methods for the estimation of tunnel loads), and the very conservative assumption of complete de-activation of all temporary supports.

When considering the statistical distribution of input parameters, we have to select Probability Density Functions (PDFs) which best describe the population of a specific parameter. In geomechanics, there are difficulties in measuring properties such as rock stresses, rock modulus or rock strength, and we have to select the values for input parameters of PDFs based on the following criteria:

- Intrinsic uncertainty;
- Experimental uncertainty;
- Heterogeneity/ Spatial variation;
- Time variation.

### 2. RS2 Model to Study Materials Parameter Variability on Lining Behaviour

Considering the given design criteria, the probability of failure is given by the grey areas in Fig. 1. By combining the probability of failure with the consequences of failure, it would result in the risk of the design, and thus, we can evaluate if this risk is acceptable. There is always some residual risk remaining even at the final design stage (the darker grey area on Figure 1), and this risk should be mitigated.

Uncertainties in the estimation of geomechanical parameters arise from the difficulty in measuring these characteristics, and the measurements process is subjected to errors due to the sampling process, sample preparation or sensitivity and calibration of the measuring devices. As a project develops, this uncertainty is reduced by acquiring repeated measurements.

---

\*Madear Gelu. Tel.: +44-7596-076-133.

E-mail address: gmadear@golder.com.

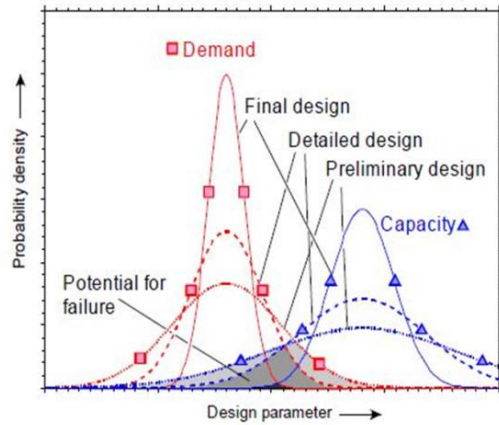


Fig. 1. Demand - capacity PDFs for tunnel lining design;

Normal probability density function, showing standard deviation ranges

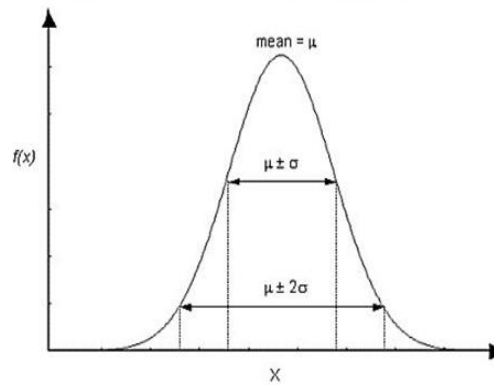


Fig. 2. The normal probability density function

Heterogeneity or spatial variation is an inherent property of the natural materials and rockmass implicitly, and rockmass property will vary within a rock unit. Thus, a failure mechanism will affect more or less severely various locations along the rock unit.

In order to determine the parameters of the Normal Distribution for each considered parameter, the Three Sigma Rule of Thumb has been used, where we estimated the highest conceivable value (HCV) of the random variable, and the lowest conceivable value (LCV). @RISK add-on for Excel has been used to derive the normal distribution for the input parameters. Fig. 3 and Fig. 4 show an example of a graphic representation of the normal distributions for both intact and residual Young's Modulus.

In all RS2 models, a Truncated Normal Distribution has been used – which is considered as the mean  $\pm$  3 standard deviations. Fig. 2 is an example of a truncated distribution, with mean  $\pm$  standard deviations.

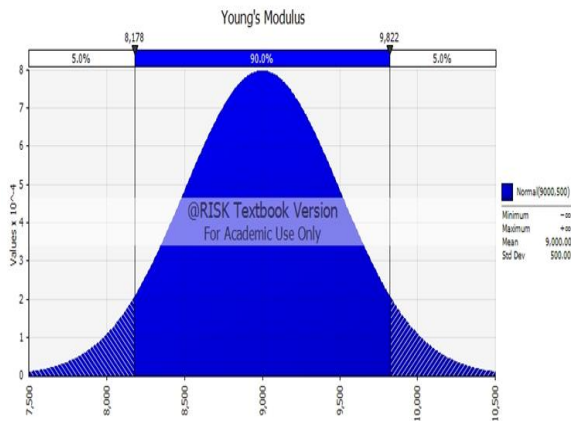


Fig. 3. Young's modulus normal distribution;

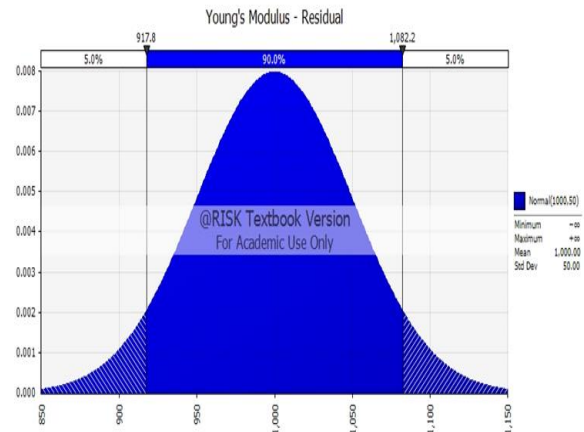


Fig. 4. Young's modulus (residual) normal distribution

## 2.1. Model Setup and Stress Path

A simple tunnel with an invert has been embedded into the rockmass, and boundary conditions have been specified. An initial stress field of sigma one = 8 MPa, sigma three = 6 MPa, sigma z = 6 MPa has been applied to the model and a plane strain analysis is performed.



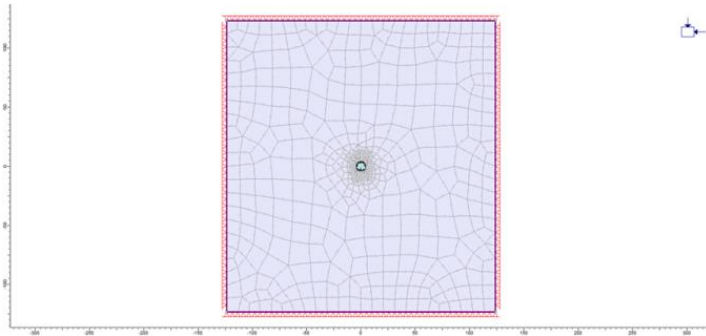


Fig. 5. RS2 model;

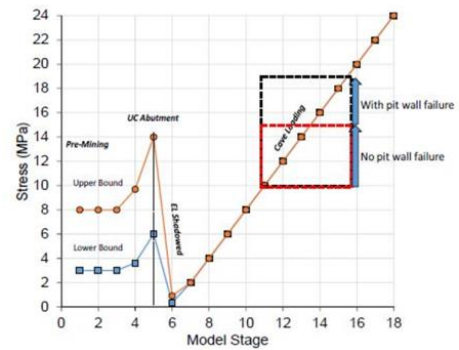


Fig. 6. Applied stress path

The general model used in this probabilistic design is represented in Fig. 5. Subsequently, a number of stress stages are applied to the model, corresponding to the loading-unloading-loading stress path for a tunnel located at Extraction Level within a block caving mining drawbell/ drawpoint – Fig. 6.

A number of 1000 samples of input parameters are generated per run, using Monte Carlo or Latin Hypercube sampling methods, and then each realisation is run independently. At the end of 1000 runs, results are assembled together as normal distributions.

## 2.2. Model 1 - Elastic-Perfectly Plastic Behaviour (Hoek-Brown Parameters Peak = Residual) + Dilation – Probabilistic with Monte Carlo Sampling

This analysis considered that the rockmass behaves elastic-perfectly plastic and the failure is given by a Hoek-Brown criterion. Input parameters are presented in Table 1, and a Monte Carlo sampling technique has been used to generate sets of parameters for each realisation from the given normal distribution.

Table 1. Input parameters for model 1

Variable Type	Material/Joint Name	Property Type	Distribution	Mean	Standard Deviation	Min	Max
Material Property	Softzone	Young's Modulus	Normal	9000	500	7500	10500
Material Property	Softzone	Intact Compressive Strength	Normal	14	1.166	10.502	17.498
Material Property	Softzone	Hoek-Brown mb parameter (peak)	Normal	13	1	10	16
Material Property	Softzone	Hoek-Brown s parameter (peak)	Normal	0.95	0.0166	0.9002	0.9998
Material Property	Softzone	Hoek-Brown a parameter (peak)	Normal	0.55	0.0166	0.5002	0.5998
Material Property	Softzone	Dilation Parameter	Normal	10	1.666	5.002	14.998
Material Property	Softzone	Young's Modulus	Normal	9000	500	7500	10500

Table 2 contains equivalent characteristics in the combined liner – steel arches (parameters are given in Table 3) and shotcrete/ concrete (characteristics presented in Table 4).

Table 2. Equivalent parameters for combined liner: concrete + steel arches

Liner Type	Reinforced Concrete
Equivalent Young's modulus	36927.4 MPa
Equivalent thickness	0.407118 m
Poisson ratio	0

Table 3. Reinforcement properties of steel arches

Type	I-beam (HP): HP360 x 152
Spacing	1 m
Section Depth	0.356 m
Area	0.0194 m <sup>2</sup>
Moment of inertia	0.000437 m <sup>4</sup>
Young's modulus	200000 MPa
Poisson ratio	0.25
Compressive strength	400 MPa
Tensile strength	400 MPa

Table 4. Concrete properties

Thickness	0.355 m
Young's modulus	30000 MPa
Poisson ratio	0.15
Compressive strength	40 MPa
Tensile strength	3 MPa

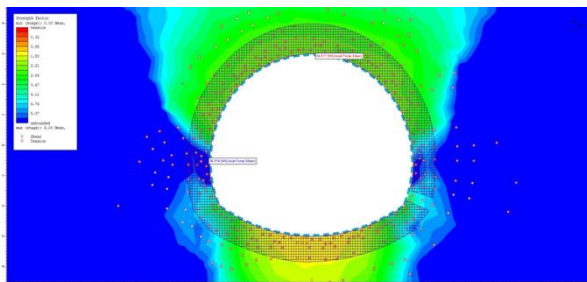


Fig. 7. Axial forces in last stage and strength factor in rockmass;

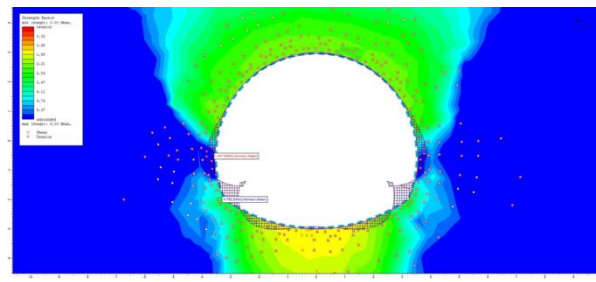


Fig. 8. Bending moments in last stage and strength factor rockmass

Results were calculated for each stage of the stress path – a total number of 18 stages were considered in the analysis.

Axial forces are represented for the last stage (highest load) in Fig. 7, whereas bending, movements acting on the combined liner are shown in Fig. 8.

As mentioned previously, results from the 1000 realisations are compound together into a normal distribution – the user has the option to plot results for each parameter around the mean of the normal distribution.

As an example, the Strength Factor in the rockmass defined as the ratio between applied stresses and rock strength is shown in Fig. 9 and Fig. 10:

Fig. 9 – for the mean +3 standard deviations, corresponding to the Best-Case Scenario; rockmass around the tunnel still present some resistance as the Strength Factor is over unit;

Fig. 10 – for the mean -3 standard deviations, corresponding to the Worst-Case Scenario; rockmass fails around the tunnel, with Strength Factor reaching values of 0.32.

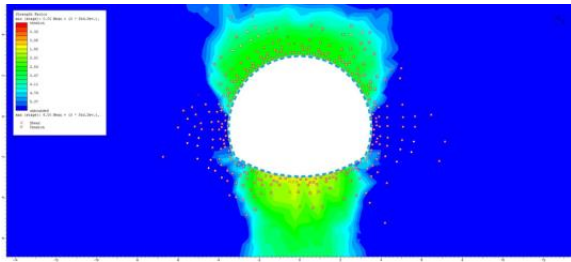


Fig. 9. Strength factor in rockmass for mean + 3 standard deviations;

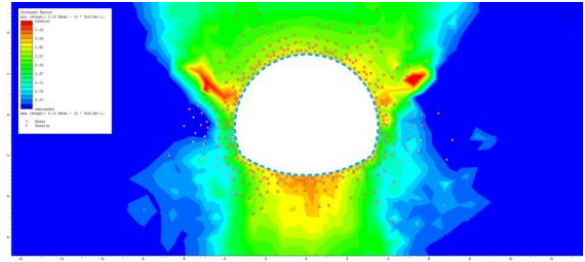


Fig. 10. Strength factor in rockmass for mean - 3 standard deviations

### 2.3. Model 2 - Model 2 - Elastic-Plastic with Strain Softening Behaviour (Hoek-Brown Parameters Peak $\neq$ Residual) + Dilation – Probabilistic with Latin Hypercube Sampling

This analysis took into account an elasto-plastic rockmass, with a strain softening post-peak behaviour. Table 2 contains input parameters for this model and the sampling technique used is Latin Hypercube.

Axial forces are represented in Fig. 11 along with the Strength Factor in the rockmass and Fig. 12 shows the bending moment applied to the combined liner.

Table 5. Input parameters for model 2

Variable Type	Material/Joint Name	Property Type	Distribution	Mean	Standard Deviation	Min	Max
Material Property	Softzone	Young's Modulus	Normal	9000	500	7500	10500
Material Property	Softzone	Intact Compressive Strength	Normal	14	1.166	10.502	17.498
Material Property	Softzone	Hoek-Brown mb parameter (peak)	Normal	13	1	10	16
Material Property	Softzone	Hoek-Brown s parameter (peak)	Normal	0.95	0.0166	0.9002	0.9998
Material Property	Softzone	Hoek-Brown a parameter (peak)	Normal	0.55	0.0166	0.5002	0.5998
Material Property	Softzone	Hoek-Brown mb parameter (residual)	Normal	1.8	0.166	1.302	2.298
Material Property	Softzone	Hoek-Brown s parameter (residual)	Normal	0.9	0.0166	0.8502	0.9498
Material Property	Softzone	Hoek-Brown a parameter (residual)	Normal	0.45	0.0166	0.4002	0.4998
Material Property	Softzone	Dilation Parameter	Normal	10	1.666	5.002	14.998

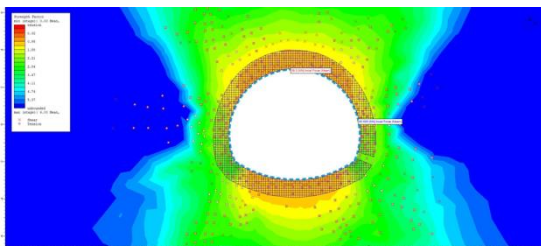


Fig. 11. Axial forces in last stage and strength factor in rockmass;

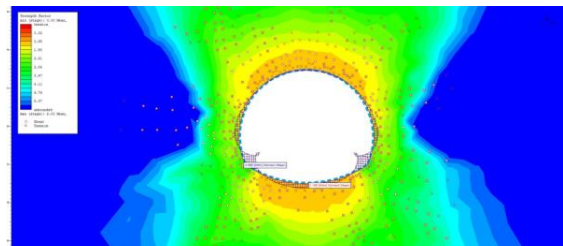


Fig. 12. Bending moments in last stage and strength factor in rockmass

### 3. Conclusions

Uncertainty in the estimation of input parameters for a tunnel lining design can be overcome by using a probabilistic approach. Using Monte Carlo simulations, implemented in Rocscience's RS2 software, axial forces (mean) and bending moments (mean) could be determined for two models with elastic-perfectly plastic and strain-softening behaviours and characterised by Hoek-Brown failure criterion.

The design engineer has a tool to predict tunnel liner/ support behaviour for various scenarios, from the Base-Case Scenario ( $\sigma + 3\mu$ ) through the Most Probable Scenario ( $\sigma$ ), to the Worst-Case Scenario ( $\sigma - 3\mu$ ).

Consideration of uncertain parameters for the liner and the derivation of the reliability index of the system rockmass – liner are the next steps of this analysis.

### References

- Fortsakis, P., Litsas, D., Kavvadas, M., Trezos, K., *Reliability Analysis of Tunnel Final Lining*, ISGSR2011 – Vogt, Schuppener, Straub & Brau (eds.) - © Bundesanstalt für Wasserbau ISBN 978-3-939230-01-4, (2011).
- Michael Duncan, J., *Factors of Safety and Reliability in Geotechnical Engineering*, Journal of Geotechnical and Geoenvironmental Engineering, (2000).
- Palisade, *@RISK for Risk Analysis*, [www.palisade.com](http://www.palisade.com).
- Rocscience, *Probabilistic Analysis in RS2 – Tutorial*, [www.rocscience.com](http://www.rocscience.com).

## Loads estimation in block caving mining

Madear Gelu<sup>a\*</sup>, Madear Camelia<sup>b</sup>

<sup>a</sup> GOLDER, 1, South Parade, Doncaster – DN1 2DY, UK

<sup>b</sup> ECO-ROCCA Engineering, 23, Parcului Street, Petrila - 335800, Romania

---

### Abstract

Block caving method of mining requires more development work before the start of ore production than most other mining methods. This mining method implies to have high investment costs and these mining methods are quite inflexible. Initiating and sustaining the cave govern the early productivity and economics of the operation. The paper presents both the theory for loads estimation and results for Monte Carlo simulations for a block caving mine, taking into account the following variables: hydraulic radius of the cave; bulk density; horizontal-to-vertical stress ratio; friction angle at the cave walls.

*Keywords:* mining, block caving, Monte Carlo simulation, hydraulic radius;

---

### 1. Introduction

The stability of the extraction level excavations is critical to the efficient extraction of the ore from caving mines. Several factors have the potential to influence the levels of stress induced in the extraction level excavation, of which significant is the vertical stress due to cave loading.

Estimation of the vertical stresses/ loads acting on the extraction level in block caving mining is paramount for the optimisation of tunnel lining/ support at the Extraction Level (EL). The limit equilibrium solution proposed by Loren Lorig is employed to estimate the average vertical stress at the cave base. Model inputs are derived from experience, theory and the results of numerical and physical experiments.

Monte Carlo simulations are used to obtain stress estimates at the cave base/ extraction level, due to the high level of uncertainty in evaluating input parameters.

In order to derive loadings on tunnels located at the Extraction Level, we should estimate stresses generated during the block cave mining processes at the base of the drawbell/ drawpoint. These loads are used subsequently into the stress path to design the lining/ support of the tunnels located at Extraction Level.

### 2. Relation Between Caved Column Height and Vertical Stress at the Cave Base

Loren Lorig derived a formula for the quantitative estimation of transmitted vertical stress at the base of a block cave, for the plane strain condition using limit equilibrium analyses.

A fundamental assumption inherent in the analyses is that the caved material is drawn uniformly, resulting in a relatively uniform vertical stress acting on the base.

It is important to note that a uniform draw is seldom achieved in practice. The problem to be analysed is represented in the Fig. 1, and the specific goal was to quantitatively derive the relationship between the base pressure,  $p$ , and the geometry of the prism.

Using the limit equilibrium methods for the three-dimensional case, Lorig derived the following formula:

$$\frac{p}{\gamma H} = \frac{1}{\frac{H}{R_H} K_p \tan \phi} \left( 1 - e^{-\frac{H}{R_H} K_p \tan \phi} \right) \quad (1)$$

---

\*Madear Gelu. Tel.: +44-7596-076-133.

E-mail address: gmadear@golder.com.

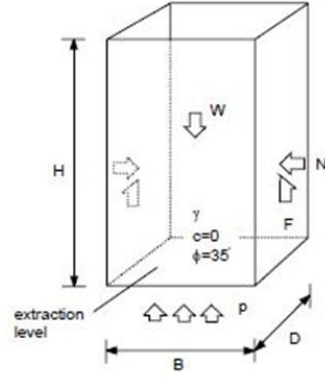


Fig. 1. Lorig representation of the cave

### 3. Estimation of Vertical Cave Loads on Extraction Level using Pierce's Model

The limit equilibrium solution adopted by Lorig is based on the bin theory of Janssen (1895), where the vertical stress – at a depth  $z$ , below the free surface of a bin is given by:

$$\sigma_v = \frac{R_h \cdot \rho_b \cdot g}{\tan \phi_w \cdot k} \left( 1 - e^{-\frac{k \cdot \tan \phi_w \cdot z}{R_h}} \right) \quad (2)$$

where:

- $R_h$  – is the bin hydraulic radius (equal to the area divided by the perimeter);
- $\rho_b$  – is the bulk density;
- $g$  – is the gravitational constant;
- $k$  – is the ratio of horizontal-to-vertical stress;
- $\phi_w$  – is the friction angle at the bin wall.

The friction angle of caved rock varies within a cave due to variability in bulk porosity, stress UCS of the rock fragments. Barton and Kjaernsly (1981) derived an empirical rockfill shear strength criterion:

$$\phi = \phi_b + R \cdot \log \left( \frac{RBS}{\sigma_n} \right) \quad (3)$$

in which:

- $\phi_b$  – is the basic friction angle, estimated from shear or tilt tests;
- $R$  – is the equivalent roughness of the caved rock – estimated from porosity and fragment roundedness/smoothness;
- $RBS$  – is the rock block strength;
- $\sigma_n$  – is the normal stress – in this case, the horizontal stress at the cave perimeter.

The initial formulation of Barton & Kjaernsli shows that Shear Strength ( $S$ ) was used instead of  $RBS$ . Their dependency is presented in (4):

$$\phi' = R \cdot \log \left( \frac{S}{\sigma_n} \right) + \phi_b \quad (4)$$

Relationship between horizontal stress, friction angle and the equivalent roughness is presented in Fig. 2.

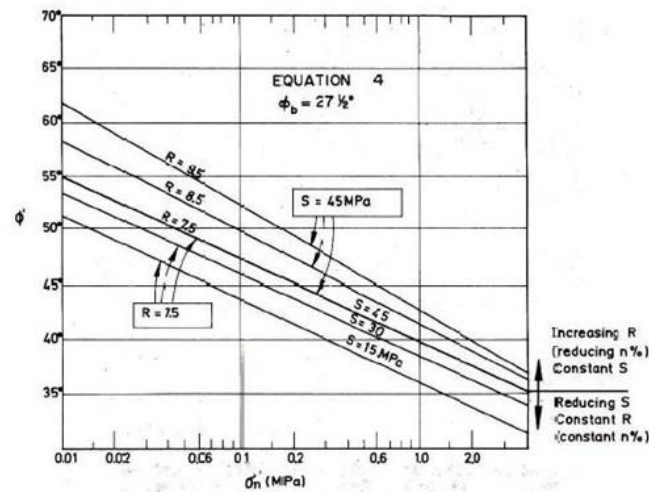


Fig. 2. Horizontal stress as a function of friction angle

#### 4. Actual Modelling using @RISK – Monte Carlo Simulations

In order to perform a probabilistic analysis of the above-presented model of the stresses/ loads at the Excavation Level, Monte Carlo simulations have been performed, using @RISK addon for Excel for Windows.

Input parameters used for simulations are presented in Table 1 – we have used Normal Distributions for the majority of parameters:

Table 1. Parameters and their normal distributions used in simulations

No.	Parameter	Distribution	Variance
1.	Hydraulic Radius, m	RiskNormal (120,10)	120±30
2.	Bulk Density, kg/ m <sup>3</sup>	RiskNormal (3200,233.3)	3200±700
3.	Gravitational Constant, m/s <sup>2</sup>	9.81	
4.	Basic Friction Angle, degrees	RiskNormal (30,1.66)	30±5
5.	H-to-V Stress Ratio	RiskNormal (0.5,0.03)	0.5±0.1
6.	Depth from Surface, m	RiskUniform (0,600)	0÷600
7.	Draw Factor	RiskUniform (2,3)	2÷3
8.	Rock Block Strength, MPa	RiskNormal (35,5)	35±15
9.	Equivalent Roughness	RiskNormal (4,1)	4±3

and input parameters for Uniform Distributions (for Model Rev. 6), are shown in Table 2.



Table 2. Parameters and their uniform distributions used in simulations

No.	Parameter	Distribution
1.	Hydraulic Radius, m	120
2.	Bulk Density, kg/ m3	RiskUniform (2550, 3050, RiskStatic (3200))
3.	Gravitational Constant, m/s2	9.81
4.	Basic Friction Angle, degrees	RiskUniform (20, 35, RiskStatic (30))
5.	H-to-V Stress Ratio	RiskUniform (0.3, 0.6, RiskStatic (0.5))
6.	Depth from Surface, m	RiskUniform (0,600)
7.	Draw Factor	RiskUniform (2,3)
8.	Rock Block Strength, MPa	RiskUniform (20, 100, RiskStatic (35))
9.	Equivalent Roughness	RiskUniform(1, 7, RiskStatic (4))

The following models were run, considering various assumptions as detailed below:

- Rev. 1 – only vertical stresses based on Lorig formula;
- Rev. 2 – Pierce’s approach with  $R=1$  and  $DF=3$ ;
- Rev. 3 –  $R$  – Normal Distribution and  $DF=3$ ;
- Rev. 4 –  $DF$  – Uniform Distribution; Full simulation using parameters as in Table 1;
- Rev. 5 – as per Rev.4 with  $R=0$ ;
- Rev. 6 - Full simulation using parameters as in Table 2.

Simulation results are contained in each Excel file generated and a summary for Rev.4, Rev.5 and Rev.6 is presented below (Fig. 3 – Fig. 9):

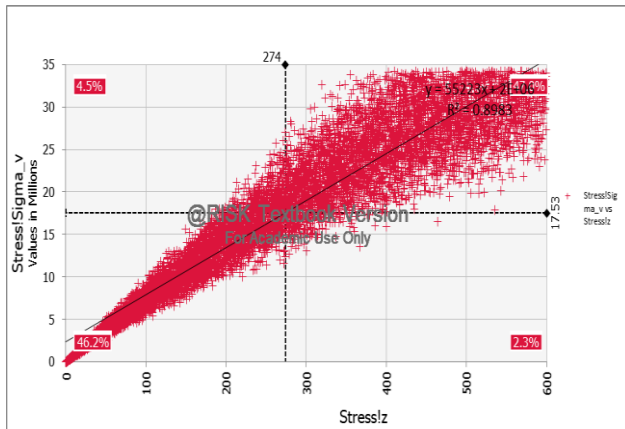


Fig. 3. Realizations for 90% confidence for model rev.4;

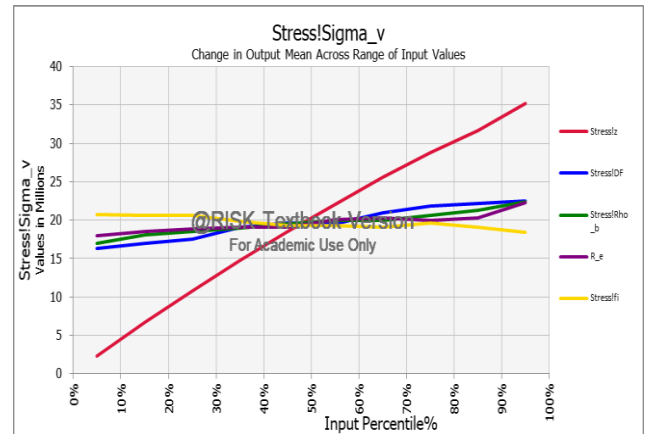
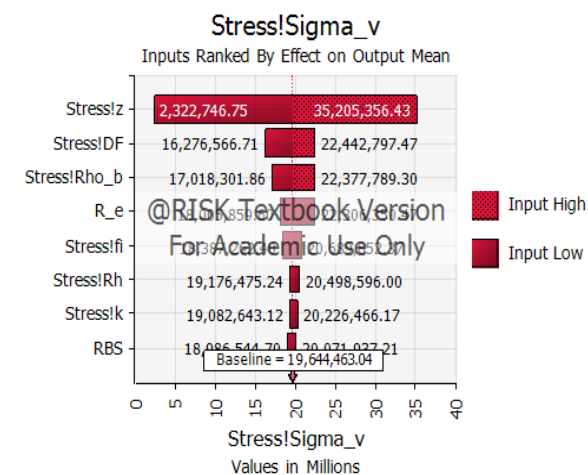
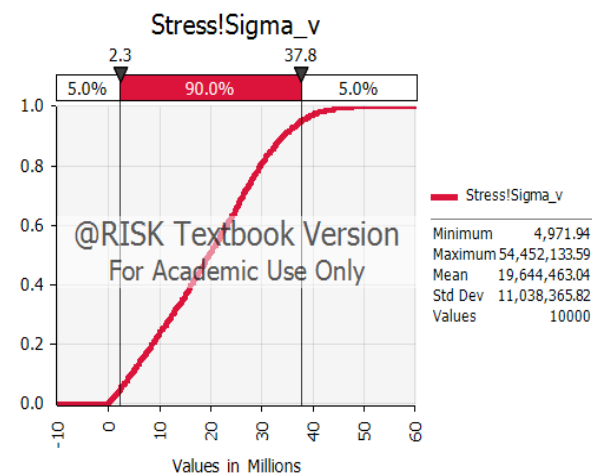
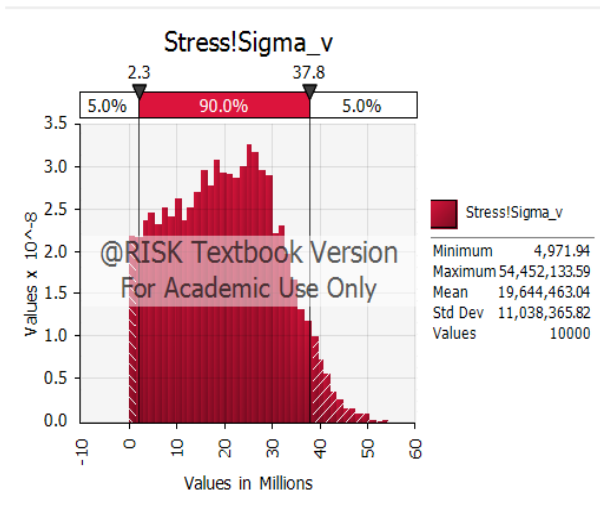


Fig. 4. Spider graph of parameter influence for model rev.4

**@RISK Output Report for Stress!Sigma\_v D15**

Performed By: Madear, Gelu

Date: 12 July 2018 15:15:48

**Simulation Summary Information**

Workbook Name	Caving Loads - MC_Rev4.x
Number of Simulations	1
Number of Iterations	10000
Number of Inputs	8
Number of Outputs	1
Sampling Type	Latin Hypercube
Simulation Start Time	12/07/2018 13:15
Simulation Duration	00:00:33
Random #Generator	Mersenne Twister
Random Seed	1208086226

**Summary Statistics for Stress!Sigma\_v**

Statistics	Percentile	
Minimum	4971.939921	5% 2317419.6
Maximum	54452133.59	10% 4478827
Mean	19644463.04	15% 6579271.8
Std Dev	11038365.82	20% 8557154.4
Variance	1.21846E+14	25% 10519172
Skewness	0.12977147	30% 12623668
Kurtosis	2.210098559	35% 14505707
Median	19646448.05	40% 16230539
Mode	21239397.28	45% 18032649
Left X	2317419.608	50% 19646448
Left P	5%	55% 21381628
Right X	37781887.18	60% 23128013
Right P	95%	65% 24754220
Diff X	35464467.57	70% 26296683
Diff P	90%	75% 27982335
#Errors	0	80% 29673755
Filter Min	0%	85% 31772196
Filter Max	100%	90% 34227493
#Filtered	0	95% 37781887

**Change in Output Statistic for Stress!Sigma\_v**

Rank	Name	Lower	Upper
1	Stress!z	2322746.7	35205356
2	Stress!DF	16276567	22442797
3	Stress!Rho_b	17018302	22377789
4	R_e	18005860	22306350
5	Stress!fi	18387262	20689852
6	Stress!Rh	19176475	20498596
7	Stress!k	19082643	20226466
8	RBS	18986545	20071937

Fig. 5. Results for Rev. 4 simulation inclusive of table statistics

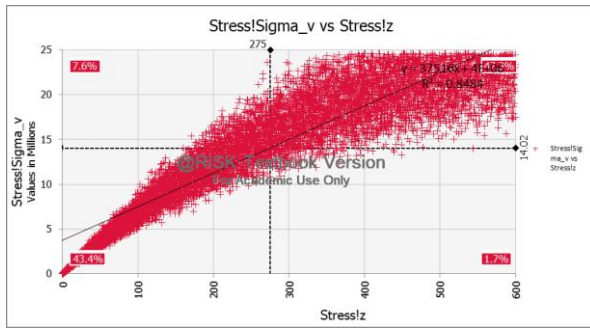


Fig. 6. Realizations for 90% confidence for model rev.5;

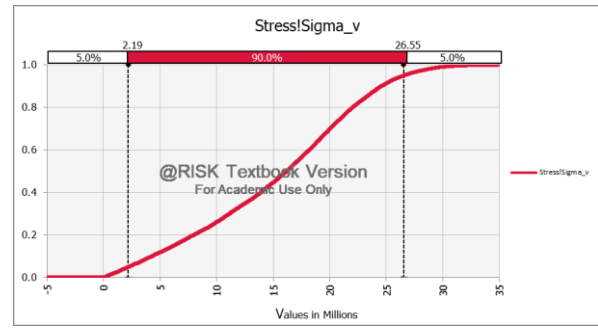


Fig. 7. Cumulative Distribution Function for caving loads (stress) for model rev.5

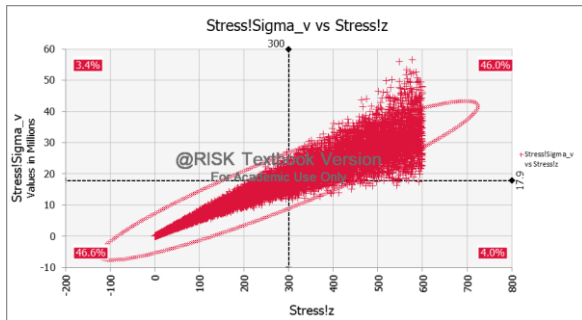


Fig. 8. Realizations within 95% ellipse confidence for caving loads (stress) for model rev.6

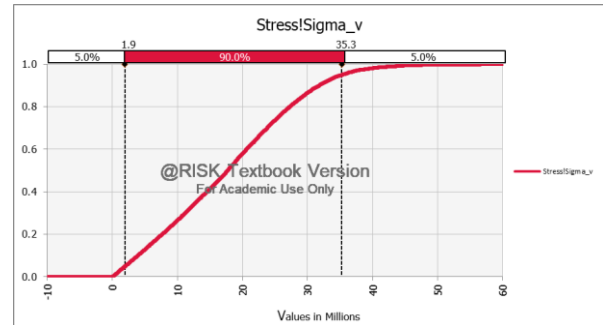


Fig. 9. Cumulative Distribution Function for caving loads (stress) for model rev.6

Fig. 3, Fig. 6 and Fig. 8 show the variation of stresses with depth at the Excavation Level.

## 5. Conclusions

- The vertical stresses on the extraction level are likely to vary from the average stress estimated by Lorig formula due to the redistributing effects of the draw;
- Physical experiments demonstrated that under less ideal draw conditions, the stress could be as much as 3 times the average vertical load;
- Incorporating a Draw Factor of 2-3 into Monte Carlo simulations, we obtain an estimate of the maximum cave load on the major apexes at various depths;
- If the footprint were consistently drawn over a smaller hydraulic radius (less than the total footprint  $H \cdot R_h$ ), these stresses would be lower due to enhanced arching of stresses into the surrounding stagnant undrawn material.

## References

- Brown, E.T., *Block Caving Geomechanics*, Julius Kruttschnitt Mineral Research Centre & The University of Queensland, (2002).
- Pierce, M., *A Model for Gravity Flow of Fragmented Rock in Block Caving Mines*, PhD Thesis, (2010).
- Palisade, @RISK for Risk Analysis, [www.palisade.com](http://www.palisade.com).

## Planning the development of mining operations under the changing demand for iron ore products

Lutsenko S.A.<sup>a\*</sup>, Zhukov S.A.<sup>b</sup>

*State Higher Education Establishment “Kryvoy Rog National University” 21/29, Lermontova st., 50002, Kryvoy Rog, Ukraine  
State Higher Education Establishment “Kryvoy Rog National University” 57, Gorno-zavodskaya st., 50004, Kryvoy Rog, Ukraine*

---

### Abstract

The article reviews the issue of planning the development of mining operations under the changing demand for iron ore products. One of problems concerning development of iron ore deposits at the present-day stage of open mining development has been described. It lies in the fact that mining enterprises operate with a constant production capacity while in the markets of mineral raw materials there is a significant fluctuation in prices and demand for their products. It is almost impossible to envisage these fluctuations in the long term, because they are mainly dependent on the state of the world economy, political situation in the country, etc. In these conditions, it is possible to significantly increase the economic efficiency of development due to implementation of a flexible change in the main parameters of the quarry, which is achieved by justified correction in the development of mining operations by changing the dimensions, parameters and design of the active part of the quarry's working area. At the same time, due to a change in the working out order for mining operations concentration sites, it is possible to provide quarry operation with a minimum current stripping ratio.

It is proposed to regulate the productivity of the open-pit by changing the wall angle of the working area of the open-pit in the areas of mining operations concentration, as well as the extent and number of these sections.

The planning technique for development of mining operations in a quarry has been developed. It differs from the known techniques due to ability to regulate the main parameters of a quarry under the changing demand for iron ore products, and also takes into account the interrelation of development system parameters that ensure ready for excavation standard ore reserve in a quarry.

*Key words:* open mining, planning of mining operations development, ore output in a quarry, reserves ready for excavation;

---

### 1. The problem and its relationship with scientific and practical tasks

Modern approaches on development of the raw materials base of plants are based on the assumption that all changes in the external environment are predictable [1], while in the markets of mineral raw materials there is a significant fluctuation of prices and demand for their products. It is almost impossible to predict these variations in the longer term, because they mainly depend on global economy condition, political situation in the country, etc. As a result, the goals of domestic mining enterprises have changed. The issues of ensuring competitiveness became paramount. Special requirements are imposed on decisions that determine volume and quality of mined ore, costs and profits of the mining enterprise, which directly depend on the main parameters of the quarries, as well as on the direction of mining operations development.

The practice of quarrying shows that during the crisis periods there is a sharp drop in stripping volumes. This decrease reflects the intention of enterprises to limit the growth of production costs due to the formation of temporary non-operating sides of quarries, as well as operating sides with elevated angles of inclination. This is in large part due to the inability of mining enterprises to ensure a flexible response to changes in domestic and external demand for products without significant growth in development costs, as deposit development projects do not provide for changes in the main quarry parameters over extended periods. Under these conditions, the actual calendar development schedule cannot remain stable for a long period of time and differs markedly from the design one, which additionally leads to a delay in stripping works, untimely transfer of mine openings and, in general, to a general deterioration of mining conditions of development. Therefore, ensuring the operational regulation of quarry main parameters becomes the issue of priority for mining enterprises.

---

\*S.A. Lutsenko.

E-mail address: lutsenkosergeia@ukr.net.

As a result of the analysis of scientific publications, it was established that the existing scientific and methodological base in the field of designing and planning of open-pit mining [2-4] does not allow to provide a flexible response to the fluctuations in demand for extracted raw materials. Modern approaches to the planning of mining development are based on the assumption that the parameters of the external and internal environment will be relatively constant, and therefore, do not provide for changes in the main parameters of the quarry in the long term. This indicates the urgency of developing new and updating the existing methods of determination of quarry main parameters and planning the development of mining operations, especially in the conditions of market economic relations that require reliable optimal design solutions.

## 2. Highlighting the unsolved problem

From a design perspective, it is important to know not only the possible value of the quarry productivity on ore or rock mass, but also how to plan the development of quarry area.

With increase in the depth of quarries, their working area increases, which leads to increase in the costs for creating and maintaining of mining operations front. To reduce the costs of mining, it is necessary to strive to ensure the size of the quarry working area at any time of its operation to be minimal, yet ensuring the implementation of the production program on ore. This can be achieved by concentrating mining operations at particular sides of the quarry.

The adopted procedure for mining of the quarry field and the entire deposit significantly influences the production capacity of the mining enterprise on crude ore and finished products [5]. At the same time, the effective functioning of mining enterprises depends largely on timely change in quarry productivity in accordance with the change in the demand for iron ore products [6]. And since the production capacity of the quarry is the main indicator that determines the scale of production, its intensity and economic efficiency, then to ensure the reaction of the mining enterprise to changes in the demand for iron ore products, it is necessary to manage the development of the quarry working area by changing the intensity and sequence of mining for its particular sides. For this, it is necessary to have a reliable methodical base of planning the development of mining operations and creation of quarries working area under any changes in the demand for iron ore products.

By management of mining operations development is meant the total sequential operations on assessment of mining operations state, change of size, parameters and design of the active part of the quarry working area, determining the direction of mining operations development and monitoring of specified technological parameters in order to maintain the required mining volume and create conditions for safe and efficient operation of the quarry.

Therefore, selection of a rational method for the development of deposit reserves is one of the main and complex tasks in designing the quarry. This task becomes even more complicated in case of change in the demand for iron ore products and, accordingly, quarry productivity on ore.

## 3. Task setting

Therefore, was set the goal to develop a procedure for planning the development of mining operations, which will allow for flexible regulation of quarry main parameters under conditions of changing demand for iron ore.

## 4. Materials statement and results

The procedure for planning of mining operations development is based on the idea of concentrating mining operations at certain sides of the quarry field (active part of the working area), the length of which is determined by optimum values of the working area width and the length of active mining front [7], which provide the normative volume of reserves ready for excavation with regard to defined quarry productivity on ore. It is proposed to regulate the productivity of the open-pit by changing the wall angle of the working area of the open-pit in the areas of mining operations concentration, as well as the extent and number of these sections. At the same time, due to the change in the order of working out the mining areas where works are concentrated, it is possible to provide the open-pit works with a minimum current stripping ratio.

The application of this procedure was studied on the example of a conditional quarry developing a steeply dipping deposit. The opening of the deposit is carried out by means of blind temporary cross-overs (fig.1).

The work flow process is as follows:

1. For the specified (designed) quarry productivity on ore, the optimal values of the width of working area and the length of active mining front, as well as the length and number of mining concentration areas in the working area of the quarry (fig.2) are determined by means of nomogram.

The number of sites involved in the work is determined by the formula (the resulted value shall be rounded up):

$$n_p = \frac{D_a}{100 - D_a}, \quad \text{pcs} \quad (1)$$

where  $D_a$  – is the active area of the working part, %.

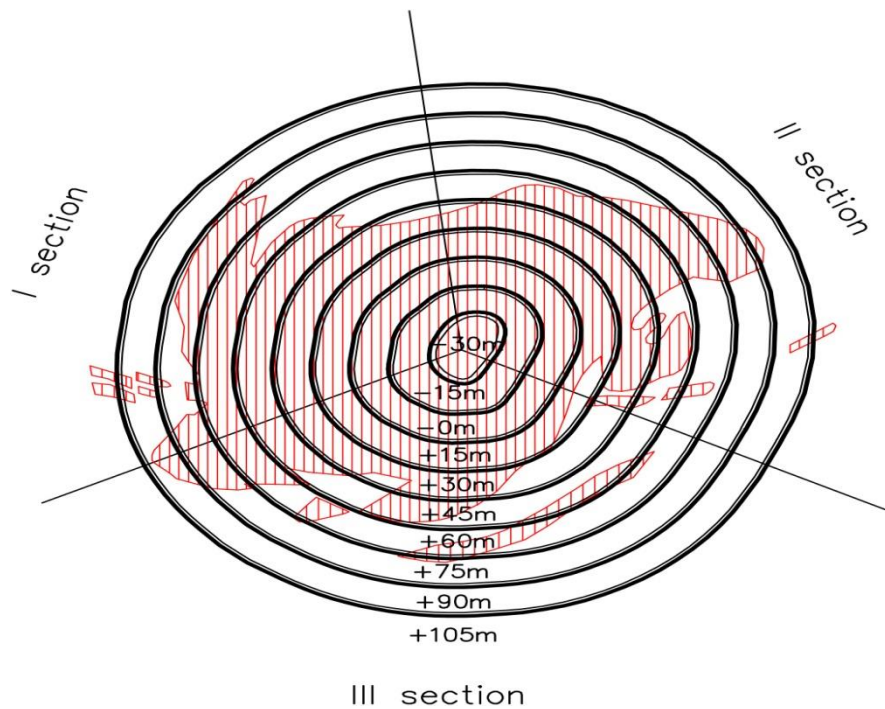


Fig. 1. Mining operations consolidated plan when reaching the mark of quarry bottom lev. -30m

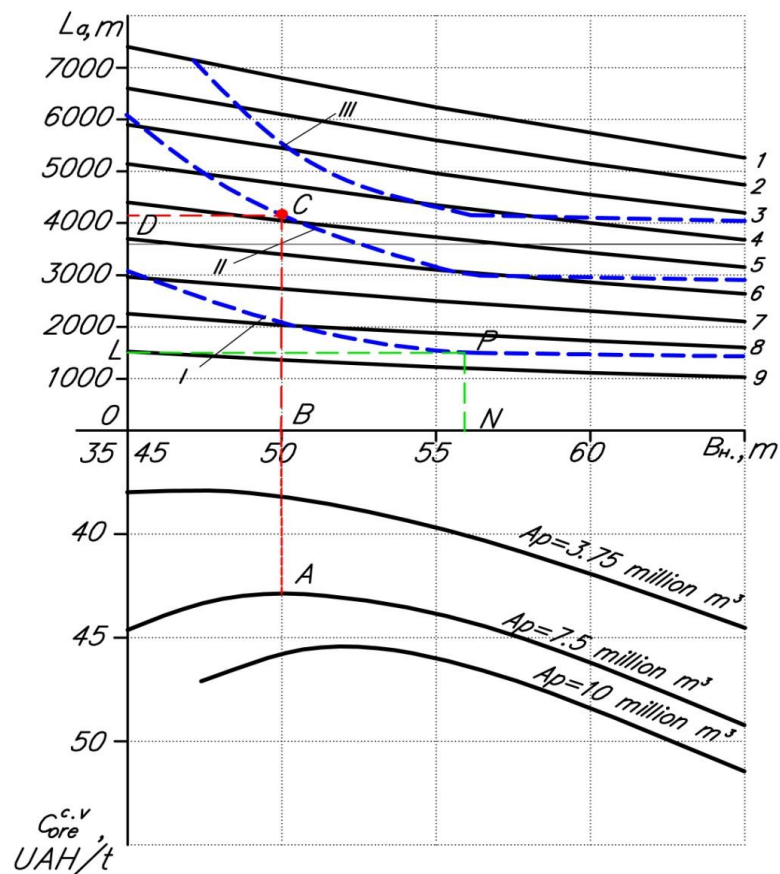


Fig. 2. Change in the length of the front of mining operations, depending on the increase in the specified width of the work site for different ore productivity options

The total number of mining concentration areas is determined by the formula (the resulted value shall be rounded up):

$$N_k = \frac{100}{100 - D_a}, \text{ pcs} \quad (2)$$



Site productivity on ore is determined by the formula:

$$A_p^s = \frac{A_p}{n_p}, \text{ t/year} \quad (3)$$

where  $A_p$  – quarry productivity on ore, t/year.

2. The quarry field is divided into equal mining concentration sites, limited with vertical planes (Fig. 1).

3. For each area, based on mining progress in depth, in accordance with the approved direction of quarry bottom sinking (the direction of the quarry bottom deepening shall be determined with consideration of operating sides slope angles, which correspond the operation with maximum possible quarry productivity on ore [8]), the maximum possible productivity and stripping coefficients with regard to their co-relation are determined [9, 10]. We build the graph of stripping current ration based on the progress in depth at each site of the deposit (Fig. 3).

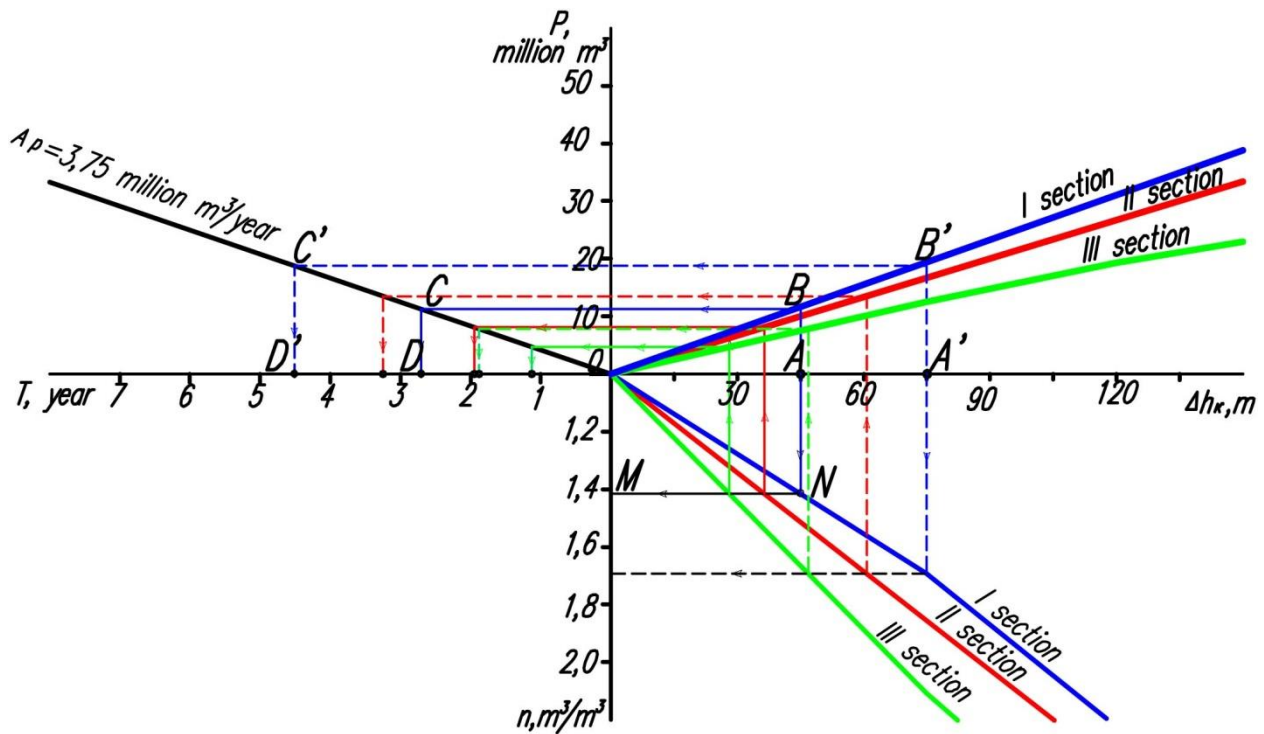


Fig. 3. Nomogram of determining the duration of quarry sites development with their different development intensity

When developing complex-structure deposits of irregular shape, ore bodies are often disturbed by faults, shifts, sometimes are bent, folded. Therefore, it is possible that at some stage of deepening the productivity on ore on the quarry in whole will be equal to the maximum possible with the corresponding width of the working platform, however, at one or more sides of the working area, the productivity will be higher or lower than the specified one. This is due to the fact that the sides of mining concentration picked on the working area do not change their spatial position during quarry sinking operations, in contrast to the ore body, which can change its shape, direction of fall, etc with the depth. Therefore, at some sides the length of active mining front on ore may increase, and decrease at others. At the same time, the length of the ore mining front on the quarry in whole will remain at the designed level.

In this case, on these sites of working area it is necessary to adjust the width of the working platform, by changing the inclination angle of the operating side of the quarry, and, accordingly, the curve of current stripping ratio at the corresponding step of sinking.

4. Determining an efficient order of quarry field development.

As we can see from fig. 3, the depth progress of mining operations at different sites of the deposit is accompanied by different stripping ratio. It is obvious that for operation of the entire quarry with minimum current stripping ratio, it is necessary to start the deepening of mining operations in the site with minimum stripping ratio until stripping ratio is of equal value with the nearest stripping ratio of any other site.

The main condition for the involvement of any section of the open-pit in the development is the equality of the current stripping ratio of this section ( $n_i$ ) and the current stripping ratio in the whole open-pit ( $n_k$ ).

Therefore, it can be affirmed that quarry operation with a minimum current stripping ratio will be ensured only if the current stripping ratio is the same in all the sites of the deposit. At the same time, the intensity of sites development will be different.



According to fig. 3, the lowest current stripping ratio and its slowest increase while deepening the quarry is observed in the site I, therefore it is best to begin mining operations from this site.

5. A long-term plan of mining operations development is drawn up.

In this regard, the duration of quarry sites mining is determined (Fig. 3) and a linear calendar plan of mining operations development is drawn up. According to the calendar plan of mining operations development compiled a summary table of increasing volumes of stripping and ore excavation in the course of quarry deepening operations, then the graphs  $V = f(P)$  are built. The graphs  $V = f(P)$  are averaged and the operating stripping ratio for the periods of quarry operation are determined.

Determination of the state of mining operations at the end of any estimated year is carried out according to the nomogram of determining the duration of quarry sites mining at different rates of sites mining intensity (Fig. 3).

In the fig. 4 showed the comparison of mining operations modes for quarry deepening:

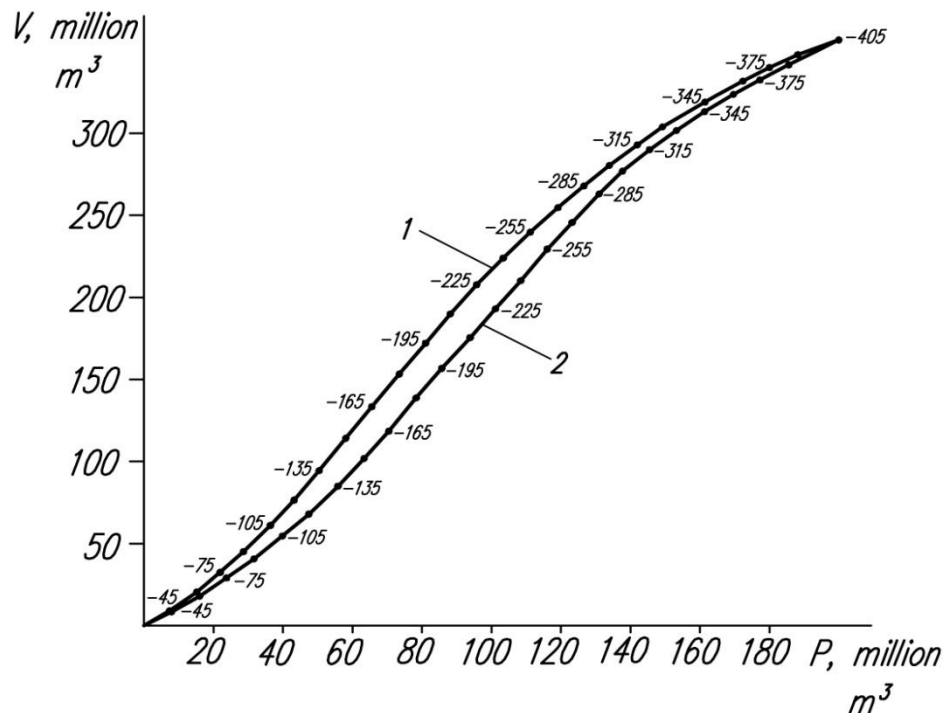


Fig. 4. Change in increasing volume of waste rocks depending on the mined volume of ore

- with a uniform development of the quarry working area (curve 1), when quarry deepening is carried out on all sites simultaneously;
- with uneven development of the quarry area (curve 2), when development of mining operations is carried out according to the developed methodology.

As can be seen from fig. 4, the curve reflecting the planning of mining operations development according to the developed methodology (curve 2) provides a better mode of mining operations than with their uniform development. In case of change in quarry productivity on ore, both upward and downward, the sequence of calculations shall be repeated starting from point 1 of this methodology.

## 5. Conclusions

As a result of the research has been developed the methodology of planning the development of mining operations in the quarry in conditions of changing demand for iron ore products, which is different from the known methodologies due to ability to regulate the main parameters of the quarry, and also considers the relationship between the width of the working platform and length of the active mining front, that provide the normative volume of reserves in the quarry ready for excavation.

The developed methodology for planning the mining operations development in an open-pit provides:

- the open-pit operation with minimum current stripping ratios at the maximum degree of mining operations concentration;
- work with a specified ore productivity.

## References

- Sokolovskiy, A.V., *Principles of designing the development of the current quarry*, Mining informational and analytical bulletin, №12, pp. 21-26, Moscow, (2007).
- Rzhevskiy, V.V., Novozhilov M.G., Yumatov B.P., *Scientific foundations for the design of quarries*, Moscow, (1971).
- Arsent'ev, A.I., Sovetov G.A., Khokhryakov V.S., Bezv N.D., Blizniukov V.H., *Planning the development of mining operations in quarries*, Moscow, (1972).
- Anistratov, Yu.I., Anistratov K.Yu., *Designing quarries*, Moscow, (2002).
- Gavrishev, S.E., Burmistrov K.V., Kolonyuk A.A., *The intensity of forming the working area of deep quarries*, Magnitogorsk, (2013).
- Lutsenko, S.A., *Open pits productivity control along with iron ore products demand variation*, *Quality – Access to Success*, vol. 18(S1), pp. 226-230, Romania, (2017).
- Lutsenko, S.A., *Determining working site width and mining front length when changing ore output of an open-pit*, Collection of research papers of National Mining University, №50, pp. 63-69, Dnipro, (2017).
- Lutsenko, S.A., *Development of method for determining maximal ore output basing on the open-pit resource availability*, *Geo-Technical Mechanics*, №130, pp. 168-175, Dnipro, (2017).
- Blizniukov, V.H., Lutsenko. S.A., *Improvement of technical criteria for comparative evaluation of mining operation options of iron ore open pits*, *Scientific Bulletin of National Mining University*, №1, pp. 44-49, Dnipro, (2017).
- Lutsenko, S.A., *Determination of an open pit performance by ore for various methods of mining operations development*, Collection of research papers of National Mining University, №52, pp. 87-92, Dnipro, (2017).

# Assessment methodology of instantaneous elastic deformation of sedimentary rocks

Toderaş Mihaela<sup>a</sup>, Danciu Ciprian<sup>a\*</sup>

<sup>a</sup>University of Petrosani, 20, University Street, Petrosani, 332006, Romania

---

## Abstract

A difficult problem that arises in experimental data processing is to establish the value of instantaneous elastic deformation. Based on the analysis of physical theories used in rheology we considered that elucidating the characterisation of rheological behaviour of sedimentary rocks can be realized taking into account the two rheological models, namely Poynting-Thomson and Burgers, through the macro-analytical theories. Regardless of the theory used in the interpretation of experimental results, the requirement to assess more accurate the elastic deformation as a hidden variable occurs. For this purpose, a graphical - analytical – experimental methodology was proposed, which we consider original and that was applied in the case of sedimentary rocks from Jiu Valley. Knowing this deformation facilitates the possibility to establish the rheological parameters and the rheological coefficients included in the nuclei of creep. Such a methodology was found, because otherwise, determining the parameters  $\alpha$ ,  $\delta$ ,  $\beta$ ,  $\gamma$ ,  $\chi$  required a whole series of integral transformations of the experimental functions that is extremely difficult.

**Keywords:** hidden variable, instantaneous elastic deformation, sedimentary rock, creep, rheological coefficients, nuclei of creep;

---

## 1. Introduction

As a result of rheological tests, especially of creep on many types of rocks in the category of low to average strength it was concluded that if maintains long time a rock under a constant load, it will fail, meaning it will break. This is due to the occurrence of the effects of viscous-plasticity, due to creep phenomenon. The literature shows that these effects are actually given by three main mechanisms that occur, namely: movement of dislocations in crystals; developing a microcracking, especially at grain contact; mineral cement's chemical alteration of the solid particles of the rock. Rheology as a science and especially rocks creep, are unfortunately still little known even now, and are still subject of numerous research studies, because all the phenomena that occur in nature and here we refer to the case of rock massifs or earth are carried out in time. Therefore, in this sense there are concerns about the behavior of rocks on the contour of the underground works, which are systems - structures that are working for a long time (whether mining works, tunnels, subways or other underground constructions). When referring to some mining workings, they can be used after the exploitation, as radioactive waste storage cavities and as a special case, a lot of attention should be given to long-term calculations of works, meaning rheological. In areas with water infiltration and where water can accumulate another phenomenon is observed, of pressure rise, leading practically to the same result. This phenomenon is known as the swelling phenomenon and occurs mainly in the presence of certain clays. If the dimensioning was not well done, the damage resulted by increasing the rocks volume can be spectacular and in the end it may even lead to breaking the apron (Toderaş, 2014).

## 2. Proposed method to assess the instantaneous elastic deformation

A difficult problem that arises in experimental data processing is to establish the value of instantaneous elastic deformation. The difficulty is primarily due to the greater curvature of the creep curve, in the initial stage of loading. To obtain this parameter we proposed a methodology (Toderaş, 2014; 2015) which consists of the following: from the row of values obtained from the creep performance of the tests, we will consider several initial values  $\varepsilon(t)$  measured at equal

---

\*Danciu Ciprian. Tel.: +40-726-351-238.  
E-mail address: CiprianDanciu@upet.ro.

intervals of time with which differences of first order, second order and so on will be calculated, based on the following relationships:

$$\begin{aligned}\Delta_n \varepsilon &= \varepsilon_{n+1} - \varepsilon_n \\ \Delta_n^2 \varepsilon &= \Delta_{n+1} \varepsilon - \Delta_n \varepsilon \\ &\dots\dots\dots \\ \Delta_n^k \varepsilon &= \Delta_{n+1}^{k-1} \varepsilon - \Delta_n^{k-1} \varepsilon\end{aligned}\quad (1)$$

where: index n represents the number of the considered point, and k – the order of difference.

By replacing the expressions  $\Delta_n^k \varepsilon$  in  $\Delta_n^{k-1} \varepsilon$ ,  $\Delta_n^{k-1} \varepsilon$  in  $\Delta_n^{k-2} \varepsilon$  and so on from the relations  $\dot{\varepsilon} = \varepsilon_0 \cdot e^{\alpha \sigma_c}$ , the general equation is obtained:

$$\varepsilon_n = \varepsilon_{n+1} - \Delta_{n+1} \varepsilon + \Delta_{n+1}^2 \varepsilon - \Delta_{n+1}^3 \varepsilon + \dots + (-1)^k \Delta_n^k \varepsilon \quad (2)$$

which will be used to establish the initial deformation  $\varepsilon_0 = \varepsilon(0)$  at  $t = 0$  according to the measured values  $\varepsilon_1, \varepsilon_2, \dots$

All terms of the relation (2) are affected by (n+1) differences, except the last term that is affected by the (n-a) difference. The calculus of the deformations differences stops at the same order, for which, in the limits of calculus, could be written that  $\Delta_0^k \varepsilon \cong \text{const}$ , for all the n values considered. This, conduct us to the idea that replacing the unknown values is allowed  $\Delta_0^k \varepsilon$ , for which  $\varepsilon_0$  must be known, through  $\Delta_1^k \varepsilon$  known, obtaining the relation to determine  $\varepsilon_0$ , as being:

$$\varepsilon_0 = \varepsilon_1 - \Delta_1 \varepsilon + \Delta_1^2 \varepsilon - \Delta_1^3 \varepsilon + \dots + (-1)^k \Delta_1^k \varepsilon \quad (3)$$

It is seen that, actually, the problem of determining  $\varepsilon_0$  is reduce to summing the data of diagonal row that begins with  $\varepsilon_1$  (see Table 1). Appraisalment of the limit value through the deformation goes:

$$\varepsilon_\infty^c = \lim_{t \rightarrow \infty} \varepsilon(t) \quad (4)$$

rising another problem, another question: *which time must we consider?* The logical answer would be "infinite", as in infinite time. If we were to accept the assertions of different researchers, the infinite should be considered as "time to achieve the low rate of deformation". According to the author (Toderas, 2014, 2015), as a criterion, we can consider the notion of infinitely large, which means that this "infinite" is "high time to infinity", meaning the time whose doubling will result in test conditions, to an increased deformation of up to 0.5 %, or a value of 0.005.

Table 1. Differences of deformations to determine  $\varepsilon_0$ :

n	t	$\varepsilon$	$\Delta \varepsilon$	$\Delta^2 \varepsilon$	$\Delta^3 \varepsilon$	$\Delta^4 \varepsilon$
0	$t_0$	$\varepsilon_0$				
1	$t_1$	$\varepsilon_1$	$\Delta_0 \varepsilon$	$\Delta_0^2 \varepsilon$		
2	$t_2$	$\varepsilon_2$	$\Delta_1 \varepsilon$	$\Delta_1^2 \varepsilon$	$\Delta_0^3 \varepsilon$	
3	$t_3$	$\varepsilon_3$	$\Delta_2 \varepsilon$	$\Delta_2^2 \varepsilon$	$\Delta_1^3 \varepsilon$	$\Delta_0^4 \varepsilon$
4	$t_4$	$\varepsilon_4$	$\Delta_3 \varepsilon$	$\Delta_3^2 \varepsilon$	$\Delta_2^3 \varepsilon$	$\Delta_1^4 \varepsilon$
5	$t_5$	$\varepsilon_5$	$\Delta_4 \varepsilon$			

Such a procedure gives a superior value for  $\varepsilon_0$ , because the curve  $\varepsilon(t)$  has the convexity through  $\varepsilon$  axis, and the first derivative around zero changes convexity clearly. Knowing the value of the instantaneous elastic deformation we can proceed to establish rheological coefficients for which the calculation methodology is based on the considered creep nucleus, meaning for the rocks for which deformation under constant load tends to an horizontal asymptote, the analytical description of creep must be based on the function and so on Abel's nucleus (Rabotnov, 1966, Toderas, 2015, Todorescu, 1986) and when the rock's creep increase unlimited it is recommended the N. Rabotnov's nucleus (Rabotnov, 1966, 1969, 1980). After marking the creep curves for each type of rock analyzed based on experimental data and their analysis, we will proceed to determine the parameters and the rheological coefficients (Toderas, 2015). The original methodology for determining, proposed and presented, was imposed to be diversified in two situations, namely: in the case of using the nucleus of Rabotnov – Rozovski and respectively, for the use of Abel-type nucleus. After the analysis of creep curves, it was found that the relation between deformation and time for some rocks, is of the

first rheological type and for others of the second rheological type. Therefore, to determine the rheological constants it was necessary to consider the integral equation of the hereditary theory of Voltaire type, expressed as:

$$\varepsilon(t) = \frac{1}{E_\infty} \left[ \sigma(t) + \lambda \int_0^t L(t, \tau) \sigma(\tau) d\tau \right] \quad (5)$$

in which:  $\varepsilon(t)$  and  $\sigma(t)$  – deformations and stresses at the time taken into consideration at the beginning of the test;  $L(t, \tau)$  – creep nucleus;  $E_\infty$  – elasticity modulus in time or rheological modulus.

Therefore, for elucidating the deformation of the rock with respect to time it is necessary to determine the modulus of elasticity and the creep nucleus type of the equation (5). The type - the nature of creep nucleus can be established (Rabotnov, 1966) based on families of rock creep curves obtained experimentally in laboratory. The literature (Reiner, 1958, Tan Tjong Tjong Kie et al., 1989, Tavroghin, 1974, Todorescu, 1986) states that as the creep nucleus for different behaviors and rocks there can be used functions as power, exponential, etc., recommending certain nuclei: Voltaire, Rabotnov, Vialov, Dafting - Abel, Boltzmann, Zaretki, Rjanitân, Rozovski, binomial nucleus, the nucleus with variable parameters etc. Analyzing these nuclei, in the context of experimental data for sedimentary rocks tested to creep, I considered that the most accurate rendering of these values from the laboratory tests can be achieved by using the development of the equation (5) by Rabotnov (Rabotnov, 1966, 1969, 1980) as a fraction - exponential function of the form:

$$L(t - \tau) = \Xi_\alpha(-\beta, t - \tau) = (t - \tau)^{-\alpha} \sum_{n=0}^{\infty} \frac{(-\beta)^n (t - \tau)^{n(1-\alpha)}}{\Gamma[(n+1)(1-\alpha)]} \quad (6)$$

where:  $\Gamma$  is the gamma function;  $\beta, \alpha$  creep parameters of the rock.

Experimental data processing based on such nucleus  $\Xi_\alpha$  is complicated (Rabotnov, 1969). This function involves both the properties of several functions, e.g. exponential, and some customizations. For example, the rheological equation of state (5) with linear fractional nucleus type (6) for  $\alpha = 0$  is transformed into an integral equation with an exponential nucleus, of the form:

$$\Xi_0(\beta, t - \tau) = e^{-\beta(t-\tau)} \quad (7)$$

Equations of this type are reduced to linear equations with constant coefficients and therefore the hereditary creep theory in this case, can be examined by the elastic - viscous environmental theory. Deciphering the functions time operators can be achieved if for the nucleus the exponential function of fractional order is used, equation (6) and the main properties of integral operators established by N. Rabotnov and M.I. Rozovski, the customizations of this properties and also the appropriate approximations.

For the situation of non linear deformation in time of the material system, N. Rozovski (Rabotnov, 1966, 1969, 1980) gives a more generalized situation, as:

$$\varepsilon(t) = \frac{1}{E} \left[ \tau(t) + \int_0^t K(t, \tau) f(\sigma) d\tau \right] \left[ \tau(t) + \int_0^t K(t, \tau) f(\sigma) d\tau \right] \quad (8)$$

where:  $f(\sigma)$  is a random function of the stress state. As a creep nucleus the exponential function of fractionary order can be used belonging to N. Rozovski (Rozovski, 1958, 1960, 1961, Todorescu, 1986, Toderas, 2015), and in this case can be given:

$$\varepsilon(t) = \varepsilon_0 \left[ 1 + a \left( 1 - e^{-b\gamma t^{1-\alpha}} \right) \right] \quad (9)$$

where:  $a = \frac{\chi}{\beta - \chi}$  and  $b = \beta - \chi$ ;  $\beta, \chi$  are the creep parameters (with the dimension  $t^{-1}$ ) and which in case of Rabotnov,

respectively Rozovski's nucleus creep, are approximated by the relations:

$$\beta = T_{rel}^{\alpha-1} \quad ; \quad \chi = \frac{E - E_\infty}{E} T_{rel}^{\alpha-1} \quad (10)$$

in which:  $T_{rel}$  is the relaxation time;  $E_0$  momentary elasticity module;  $E_\infty$  is the rheological elasticity module; ( $E_\infty < E$ );  $\alpha, \gamma$  are coefficients that characterize the rocks' creep and that can be experimentally determined; they do not have a constant value, no matter the type of rock, as Rabotnov notes (Rabotnov, 1966). We mention that for the case in which  $\beta - \chi > 0$ , the creep curve that corresponds to Rabotnov, respectively Rozovski's nucleus, is the primary creep curve and is limited by the value of deformation.

If still  $\beta < \chi < 0$ , without excluding the situations when  $\beta < 0$ , than the parameters of creep loose their sense given by the relation (10) and it will pass at Abel's nucleus, meaning an unlimited creep in which:  $\varepsilon(t=\infty) = \infty$  or:

$$\frac{\varepsilon(t) - \varepsilon_0}{\varepsilon_0} = a \left( 1 - e^{-b\gamma t^{1-\alpha}} \right) \quad (11)$$

in which:  $\varepsilon_0$  is the relative deformation at the beginning of load ( $t = 0$ ), meaning the instantaneous elastic deformation (Toderas, 2015);  $a$  and  $b$  are experimental coefficients;  $\alpha$  is a non-dimensional coefficient equal according to N. Rabotnov (Rabotnov, 1966) with 0.7 for rocks, affirmation that is still approximate and orientative, reason for which we recommend its experimental determination for each type of rock;  $\gamma$  is a calculated parameter:

$$\gamma = (1 - \alpha)^{1-\alpha} \quad (12)$$

that for the rocks is:  $\gamma = 0.6968453 = 0.697$  according to N. Rabotnov (Rabotnov, 1966).

Resolution is to establish the coefficient  $a$  of the relation (11) and with the help of creep curves for  $t = \infty$ , value then replaced in the same expression (11) will obtain a range of values of  $b$  for different times  $t$ , from which we calculate the value of  $b$  as an arithmetic average. Rabotnov's nucleus creep,  $K(t - \tau)$  depends of parameters  $\alpha$  and  $\beta$ . Experimental data processing based on such a nucleus is complicated (Rabotnov, 1966) because it requires a whole series of integral transformations of the experimental functions and that the values of the parameters do not have sufficient physical clarity. As a result, we can specify the following: the norm of N. Rabotnov's functions depends of the size of  $\beta$ ; the size of  $\beta$  depends of  $\alpha$ , including the time at order  $-(1+\alpha)$ ; for all rocks and other materials, sizes and  $\alpha$  and  $\beta$  are negative, although analyzing data from the literature shows that in the works of Rabotnov all these parameters appear as positive, while a number of other authors parameters  $\alpha$  and  $\beta$  are accompanied by a minus sign. Such a finding leads to a different understanding of the meaning of those parameters; in the expression that describes the flow curve the size is included  $(\alpha + 1)$  and a parameter  $\alpha$ . It is desirable that in the creep nuclei to enter this size,  $\alpha$ , determined directly by experiment. All these findings lead to the idea to propose the following form of the Rabotnov and Abel's nuclei (Ruppenet et al., 1962), expressions in which  $\xi$  is always positive, and  $t_0$  has the sense and value of delaying time ( $T_{int}$ ). In this basis, the connection between parameters  $\alpha$ ,  $\beta$ ,  $\xi$ ,  $t_0$  can be determined, and also, the connections between the functions of Rabotnov and the proposed one; according this, in the expression of Volter – Boltzmann that we obtained,  $\alpha_\infty$  has a physical sense of ratio between stabilized total deformation  $\varepsilon_t$  and instantaneous elastic deformation  $\varepsilon_{ei}$ :

$$\alpha_\infty = \frac{\lambda}{-\beta} + 1 \quad \text{or} \quad \alpha_\infty = \frac{\varepsilon_t}{\varepsilon_{ei}} \quad (13)$$

Considering the normal deformation at creep for a constant stress  $\sigma_0$  (or with a certain solicitation level  $\Delta_i$ ) and using the expression  $\lim_{t \rightarrow \infty} \int_0^t \exists_\alpha(\beta, t - \tau) d\tau = -\frac{1}{\beta}$ , it is found that:

$$\lim_{t \rightarrow \infty} \varepsilon(t) = \lim_{t \rightarrow \infty} \int_0^t K(t_0, t - \tau) d\tau = 1 \quad (14)$$

This expression allows to construct standardized graphics for processing the results of creep. Graphics can be built based on tables (Rabotnov, 1966) in which the function values are given:

$$F_2(\alpha, x) = \frac{1}{t^{\alpha-1}} \int_0^\infty \exists_\alpha(-\beta, t) d\tau = \sum_{n=0}^\infty (-1)^n \frac{x^n}{\Gamma[(\alpha + 1)(n + 1) + 1]} \quad (15)$$

where:  $x = \xi(t) = \beta t^{\alpha+1}$ .

Using the relation between function of Rabotnov and the proposed one and also the obtained relations, it is seen that:

$$\varepsilon(t) = x(t) F_2[\alpha, x(t)] \quad (16)$$

reason for which the ordinates axis will give the value of the right side of the relation (15), and the abscise axis the logarithm of corresponding time:

$$\lg \frac{t}{t_0} = \frac{1}{\alpha + 1} \lg x \quad (17)$$

Such graphics, for  $0.1 \leq \xi \leq 0.9$ , are given in Figure 1. In this representation, the unit of measurement of time on the x-axis is regarded as the size of  $t_0$ , and for the measurement of deformations on the ordinate axis is considered to be the maximum creep deformation. Analysing such a chart, it is seen the particularity of high practical importance, namely, that all curves intersect near a single point in which the normalization function of creep is 0.50 of its maximum value, size for which the value  $t/t_0$  remains almost the same and can be considered constant,  $t^* = 0.640 \cdot t_0$  for any  $\xi$ , which enables the determination of the value of  $t_0$ , independent from the value of  $\xi$  which is extremely important in experimental data.

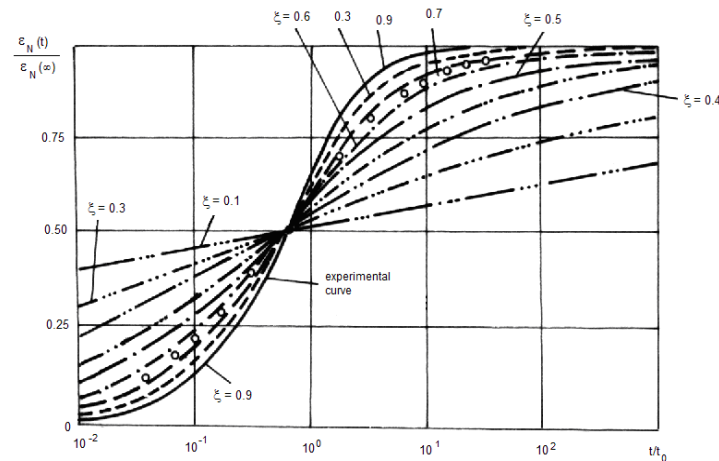


Fig. 1. Normation curves of creep

According to this proposed methodology, the calculus stages are:

1. Rock type, monoaxial compressive strength, loading degree and creep determinations;
2. Establishing the solicitation interval  $t_{\infty}$ ;
3. Calculus of the value of deformation  $\varepsilon_N(t) = \varepsilon(t) - \varepsilon(0)$ ;
4. Calculus of normal deformation at creep:
5. Mentioning the time  $t^*$ , for which  $\varepsilon_N^{NF}(t^*) = 0.5$ ;
6. Establishing the time  $t_0 = t^*/0.64$ ;
7. Calculus of logarithm  $\lg(t/t_0)$  for different values of  $t$ ;
8. Constructing the norm graphic of creep in coordinate system  $[\lg(t/t_0); \varepsilon_N^{NF}(t)]$ ;
9. Overlaying the norm graphic over the standard graphic (the nomogram from Figure 1), stage that allows determining the parameter  $\xi$ ;
10. Calculus of the parameters  $\alpha_{\infty}$ ,  $\alpha$ ,  $\beta$ ,  $\lambda$ .

### 3. Results and discussions

Referring to this methodology, we mention that the time that is taken into account is the one whose doubling leads in terms of experimentation conditions, to an increase of deformation up to 0.5 % meaning 0.005. In Table 2 are shown the values of the instantaneous elastic deformation obtained for the categories of analyzed sedimentary rock (Toderas, 2015).

Table 2. Instantaneous elastic deformation of sedimentary rocks studied in rheological context:

PARAMETERS Analyzed litotypes of rocks at creep in laboratory	Monoaxial compressive breaking strength $\sigma_{rc}$ [MPa]	Tests realization time, $t$ , [hours / days]	Elastic deformation $\varepsilon_e$ and instantaneous $\varepsilon_{oi}$ in the field of stability, $\cdot 10^{-2}$ [%]	The value of creep deformation $\varepsilon_{\infty} \cdot 10^{-5}$ , [%]	Ratio $\frac{\varepsilon_{\infty} - \varepsilon_{oi}}{\varepsilon_{oi}}$
Compact clayey sandstone unstratified gray - brown (Sample 6)	53.0	1,820 / 75.833	1.574326 52.4834	75,319	0.4351
Compact marl unstratified slightly schistous black - brown (Sample 10)	59.6	910.08 / 37.92	1.543215 57.757	63,697	0.364
Compact marl (massive) gray - brown (Sample 11)	78.41	1,270.08 / 52.92	2.0403 51.746	67,615	0.306
Clayey marl gray - greenish with fissures of $\text{CaCO}_3$ (Sample 12)	29.4	1,590 / 66.25	2.4094 33.511	58,851	0.803
Conglomerate (Sample 17)	14.62	1,085 / 45.208	1.60433 14.846	25,108	1.698
Arenaceous clay reddish – greenish (Sample 19)	46.0	1,032 / 43	1.5092 38.35425	47,153	0.533
Compact marly arenaceous clay gray - greenish (Sample 28)	35.8	1,124 / 46.83	2.2896 28.73878	45,317	0.764
Chocolate clay (Sample 29)	15.4	1,479 / 61.625	2.3612 21.92741	29,440	1.43
Compact gray marl with fissures of $\text{CaCO}_3$ (Sample 33)	68.0	1,236 / 51.5	1.7775 81.899	88,714	0.399
Quartz sandstone fine grained gray - greenish (Sample 37)	75.0	1,092 / 45.5	1.6745 76.396	68,751	0.361
Compact clayey sandstone fine grained gray - greenish (Sample 38)	45.7	1,116 / 46.5	1.51647 22.1722	33,429	0.507
Compact siliceous sandstone fine grained micaceous gray - greenish (Sample 39)	61.3	1,152 / 48	2.9516 62.97684	53,315	0.341



Quartz carbonate sandstone (Sample 44)	72.0	1,260 / 52.5	2.8465 65.5876	78,900	0.399
Compact gray clay (Sample 51)	24.9	706 / 29.416	2.41674 16.7443	32,869	0.96
Compact arenaceous marly clay slightly micaceous gray-greenish (Sample 59)	19.3	531 / 22.125	1.86735 43.93276	48,927	1.63
Very compact clay dark gray, (Sample 25)	32.3	5,196 / 216.5	2.34671 66.61054	83,562	0.671
Compact clayey sandstone fine grained gray - greenish (Sample 55)	52.8	1,810 / 75.46	1.60089 108.0042	85,382	0.423

Setting the parameters of creep nucleus was performed by own methodology. For studied rocks, the values of these parameters of creep ( $\alpha$ ,  $\delta$ ,  $\beta$ ,  $\gamma$ ,  $\chi$ ), changes in the range: for category of rocks with  $\sigma_{rc} < 25$  MPa ( $\alpha = 0.579 - 0.9136$ ;  $\beta = 0.00055834 - 0.195243$ ;  $\gamma = 0.695 - 0.80931$ ;  $\delta = 0.136 - 0.6043$ ;  $\chi = 0.0039 - 0.0903$ ); for category of rocks with  $25 < \sigma_{rc} < 55$  MPa ( $\alpha = 0.69873 - 0.893$ ;  $\beta = 0.087666 - 0.2547$ ;  $\gamma = 0.696 - 0.782$ ;  $\delta = 0.12493 - 0.655718$ ;  $\chi = 0.017052 - 0.21158$ ); for category of rocks with  $\sigma_{rc} > 55$  MPa ( $\alpha = 0.781666 - 0.896477$ ;  $\beta = 0.0275076 - 0.44474$ ;  $\gamma = 0.717312 - 0.79074$ ;  $\delta = 0.457 - 1.217101$ ;  $\chi = 0.06499 - 0.440$ ). Regardless of the theory used in the interpretation of experimental results, from the beginning it was necessary a proper assessment of the elastic deformation as a hidden variable (Toderas, 2015).

#### 4. Conclusions

We proposed a graphical - analytical – experimental methodology which we consider original. The need to know this deformation was to facilitate as much as possible the determination of rheological parameters and the coefficients included in the creep nuclei. We searched for such a methodology, because otherwise, determining the parameters ( $\alpha$ ,  $\delta$ ,  $\beta$ ,  $\gamma$ ,  $\chi$ ) required a whole series of integral transformations of the experimental functions which were extremely difficult. So we resorted to establish a standardization process based on the norming the function of Rabotnov, developing it for the nucleus of Abel and Rozovski (introducing a parameter  $\xi$ ) precisely because in relation appears  $(\alpha + 1)$  and not  $\alpha$ . We determined the way of evaluating the normed creep deformation, on which we have built a standardized chart through which is determined the normal function  $\varepsilon^{NF}(t)$ ; we determine the value of the parameter  $t^*$  for which  $\varepsilon^{NF}(t^*) = 0.5$  resulting the delay time  $T_{int}$  noted  $t_0$  and finally, graphics are drawn in coordinates  $[\lg(t/T_{int} = t/t_0), \varepsilon/\varepsilon_\infty]$ . By overlapping these graphics resulting from experimental measurements over the standardized ones (established for  $0.1 < \xi < 0.9$ ), we determine the appropriate value of  $\xi$ . Based on this value, we set the parameters:  $\alpha$ ,  $\beta$ ,  $\gamma$ ,  $\delta$  and  $\chi$ .

#### References

- Toderas, M., *Mecanica rocilor, pământurilor și construcții subterane*. Editura Universitas, Petroșani, ISBN 978-973-741-381-9, 1167 pg., Vol. I-II, (2014).
- Toderas, M., *Rocks rheology in the stability of underground mining works. Study case: Sedimentary rocks from Jiu Valley, Romania*. Saarbrücken, Germany - Scholars' Press International Publishing House, Lambert Academic Publishing, ISBN 978-3-639-76796-4. 549 pg., (2015).
- Rabotnov, Iu. N., *Polzucesti elementov konstrukcii*. Nauka, Moskva, (1966).
- Todorescu, A., *Reologia rocilor cu aplicații în minerit*. Editura Tehnică București, (1986).
- Rabotnov, Iu. N., *Tabliți grobno experimentalnoi funkții otriatelnâh parametrov i integrala ot nee*. Nauka, Moskva, (1969).
- Rabotnov, Iu. N., *Elements of Ereditar solid*. Mech. Mir. Publ. (traducere din limba engleză), Moscow, (1980).
- Reiner, M., *Rheology Handbuch der Physik*. Spring Verlag, Berlin, (1958).
- Tan Tjong Kie, We Hai Qing, *Creep and time-dependent dilatancy of rock at large depths*. Proc. Int. Symp. on Rock at Great Depth, Pan. 28-31 August 1989, Publ. Rotterdam, Balkema, (1989).
- Tavroghin, A.N., *Polucesti i vremmonaia zavisimosti procinosti gornâh porod*. F.T.P.R.P.I., Nr.6, (1974).
- Rozovski, M.I., *Izucenie napriajenogo sostoiania vokrug gorizontальной vârabotki s ucetom posledestva v gornâh porodah*. Izv. AN URSS OTN, (1958).
- Rozovski, M.I., *Obrabotka krivâh polzucesti na osnove integralnâh upravenii*. Izv. Vuzov Mașinstroenie, Nr.3, (1960).
- Rozovski, M.I., *Polzucesti i dlitelnoe razrușenie materialov*. Jurnal Tehn. Fiz., Nr.11, (1961).
- Ruppeneit, K.V., Liberman, Iu.M. - *Rascet krepî sahtnîh stvolov*. Izd. URSS. Moskva, (1962).

## The development of mineral triangulation networks using a simplified calculation process

Filip Ofelia-Larisa<sup>a\*</sup>

<sup>a</sup>University of Petrosani, 20, University Street, Petrosani, 332006, Romania

---

### Abstract

The procedure refers to dependent triangulation networks, and consists in the simultaneous utilization of the theory of indirect measurements and conditioned measurements. The use of indirect measurement theory and conditional measurements means a low volume of computation completed by simple matrix relations applied convincingly in practice.

In order to reduce the processing of the measured quantities, there is still a process in which the theory of the indirect measurements and the theory of the conditioned measurements are applied to the dependent triangulation networks, very frequent networks encountered in the mining basins.

Thus, with regard to the mining domain, it follows that triangulation networks play a decisive role in the good development of topographic activity through which multiple mining problems are solved.

The specificity of triangulation networks in support of the overall mining activity is that they develop on surfaces corresponding to mining basins. The form of these mining triangulation networks as well as the density of the points forming them depends on the shape of the mining basin, the number and position of the mining operations within the basin.

**Keywords:** Mining surveying, topographic underground networks, errors, topographic measurements;

---

### Introduction

It is known that the purpose of triangulation networks is to determine on a certain surface and plurality of points of a certain density.

These fixed points will continue to constitute support and control points for the set of topographic works developed according to the nature of the construction works (industrial, civil, communication, mining, etc.) which it serves to achieve and their tracking over time (Dima, 2005b).

Regarding the way of determining the triangulation points in such networks it is specified that they can result from the accumulation of the order of I, II or III geodetic points, obtaining points of order IV and V or by solving dependent triangulation networks.

The two methods for determining triangulation points have different theories to support the measurement of measured quantities. It is the theory of indirect measurements applied to the determination of points by framing and the theory of conditional measurements applied to the determination of points by independent triangulations (Dima, 1997, 1999).

We consider the dependent triangulation network formed by the old points (whose coordinates are known) A, B, C, D, E, F and new points P1, P2, Q, S (the coordinates of which are to be determined) (fig. 1).

---

\*Filip Larisa. Tel.: +40-764-422-894.  
E-mail address: larisafilip@yahoo.com.

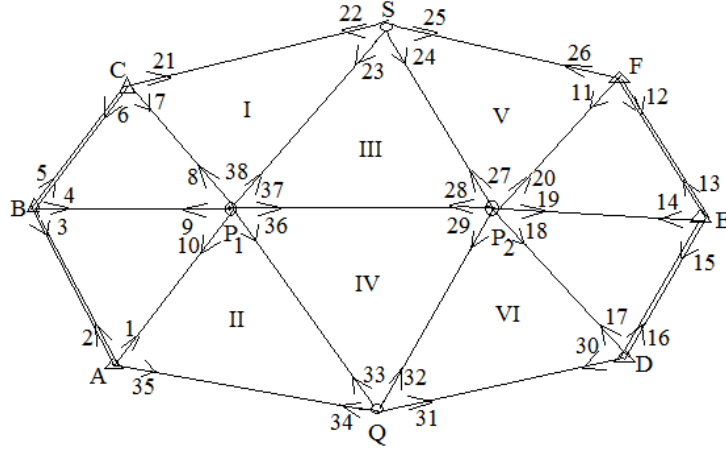


Fig. 1 - Triangulation network

By abandoning the processing of the measured magnitudes, according to the theory of conditional measurements applied to the triangulation network, as a whole it was envisaged, (Dima, 2005a):

- In the peripheral areas using the old points A, B, C, D, E, F apply the theory of indirect measurements.
- In the triangles I, II, ..., VI, respectively in the central area of the triangulation to apply the theory of conditional measurements.

According to this process there is obtained:

$$\begin{aligned} a_1 \Delta x_1 + b_1 \Delta y_1 - \Delta z_A + l_1 &= v_1 \\ -\Delta z_A + l_2 &= v_2 \\ \dots\dots\dots \\ C_{20} \Delta x_2 + d_{20} \Delta y_2 - \Delta z_{P_2} + l_{20} &= v_{20} \end{aligned} \quad (1)$$

By eliminating the unknown  $\Delta z$  the following equivalent system is obtained:

$$\begin{aligned} A_1 \Delta x_1 + B_1 \Delta y_1 + l_1 &= v_1 \\ \dots\dots\dots \\ C_{20} \Delta x_2 + D_{20} \Delta y_2 + l_{20} &= v_{20} \end{aligned}$$

Or:

$$\begin{array}{rcl} v_1 & +A_1 \Delta x_1 + B_1 \Delta y_1 & +l_1 = 0 \\ v_2 & +A_2 \Delta x_1 + B_2 \Delta y_1 & +l_2 = 0 \\ v_{20} & +C_{20} \Delta x_2 + D_{20} \Delta y_2 + l_{20} & = 0 \end{array} \quad (2)$$

To which the system is added:

$$\begin{aligned} v_7 - v_8 - v_{21} + v_{22} - v_{23} + v_{38} + \omega_I &= 0 \\ -v_1 + v_{10} + v_{38} - v_{36} + v_{33} - v_{34} + \omega_{II} &= 0 \\ v_{23} - v_{24} + v_{27} - v_{28} + v_{37} - v_{38} + \omega_{III} &= 0 \\ v_{28} - v_{29} + v_{32} - v_{33} + v_{36} - v_{37} + \omega_{IV} &= 0 \\ -v_{11} + v_{20} + v_{24} - v_{25} + v_{26} - v_{27} + \omega_V &= 0 \\ v_{17} - v_{18} + v_{29} - v_{30} + v_{31} - v_{32} + \omega_{VI} &= 0 \end{aligned} \quad (3)$$

The system consisting of literary (2) and (3) literary is written:

$$\begin{aligned} a_1 v_1 + \dots + a_{38} v_{38} + A_1 \Delta x_1 + B_1 \Delta y_1 + C_1 \Delta x_2 + D_1 \Delta y_2 + l_1 &= 0 \\ b_1 v_1 + \dots + b_{38} v_{38} + A_2 \Delta x_1 + B_2 \Delta y_1 + C_2 \Delta x_2 + D_2 \Delta y_2 + l_{20} &= 0 \\ \dots\dots\dots \\ r_1 v_1 + \dots + r_{38} v_{38} + A_r \Delta x_1 + B_r \Delta y_1 + C_r \Delta x_2 + D_r \Delta y_2 + \omega_{IV} &= 0 \end{aligned} \quad (4)$$

Number of equations:

$$r = 20 + 6 = 26$$

The number of unknowns:

$$n = 38 + 4 = 42$$

Or the matrix has the form:

$$av + Ax + \omega = 0 \quad (5)$$

The following is added to the system (5):

$$F = v'v - 2K'(av + Ax + \omega) = \min$$

The minimum condition leads to the system:

$$\begin{aligned} \frac{\partial F}{\partial v} &= 2v - 2A'K = 0 \\ \frac{\partial F}{\partial x} &= 2A'K = 0 \end{aligned}$$

Where from:

$$\begin{aligned} v &= A'K = 0 \\ A'K &= 0 \end{aligned} \quad (6)$$

With relations (6) the system (5) becomes:

$$\begin{aligned} aa'K + Ax + \omega &= 0 \\ A'K &= 0 \end{aligned} \quad (7)$$

By solving the system of normal equations (7) it follows:

$$K = -(aa')^{-1}(Ax + \omega)$$

and as a consequence:

$$x = -[A'(aa')^{-1}A]^{-1}A'(aa')^{-1}\omega \quad (8)$$

With the values of the matrix x the correction matrix v is obtained with the equality:

$$v = -a'(aa')^{-1}(Ax + \omega) \quad (9)$$

Note:

The calculation volume is reduced if the expressions of corrections in the equation system (2) are introduced into the equation system (3) (Dima, 2014).

A system is obtained with:

-6 equations  
-34 unknown

## Conclusion

The work was done on the basis of how to define such mining triangulation networks and their importance in solving the problems of elevation and topographic plotting in a unitary way, for multiple fields of activity, including the exploitation of useful minerals through underground mining works and up-to-date.

The processing of the measured quantities in order to determine the corrections on the directions and the corrections on the coordinates of the points P1 and P2 with the simultaneous use of the theory of the conditional measurements and the theory of the indirect measurements requires a small volume of calculation to obtain a system consisting of 6 equations. The use of matrix calculation methods in defining the theoretical background of the problem has led to easy obtaining simple matrix relations with direct and convenient applicability in the practical processing of measurements.

I mention that the presented analyzes use the matricial calculation with which the form of the error equations systems of the systems of normal equations and the determination of the probable values with the corresponding precisions are adaptable to the computer system.

It is possible to evaluate the clearing afterwards.

## References

- Dima, N., Pădure, I., Herbei, O., *Mine surveying*, Publisher Corvin, Deva, România, (1997).
- Dima, N., et.al., *Measurement error theory*, Universitas Publishing House, Petroșani, (1999).
- Dima, N., *Geodesy*, Universitas Publishing, Petrosani, (2005a).
- Dima, N., Herbei, O., Vereș I., Bendea, H., Filip, L., *General topography and elements of topography Mining*, Universitas Publishing, Petrosani, (2005b).
- Dima, N., Filip, L., *Specialised mining topography*, Universitas Publishing House, Petrosani, (2014).

## Improvement of blasting operations in open pit by differential strain and symmetrical blasting of the rock

Zhukov S.A.<sup>a\*</sup>, Skachkov A. A.<sup>b</sup>, Titov D.A.<sup>a</sup>

<sup>a</sup>State Higher Education Establishment «Kryvyi Roh National University» 57, Gorno-zavodskaya st., 50004, Kryvyi Roh, Ukraine

<sup>b</sup>PJSC "Northern Mining and Processing Enterprise" 15/19, Lermontova st., 50002, Kryvyi Roh, Ukraine

---

### Abstract

The purpose of the research is to analyze the patterns of the spatial concentration of explosive energy in a rock massif, which has a complex structure and caused by it the acoustic anisotropy, depending on the design of the borehole charge and the conditions for its blasting; the substantiation of the general approach to the development of technology for the destruction of rock massif under symmetrical effect of the borehole charges. The main factors influencing the impact of the explosion on the quality of the crushing rock under the conditions of application of authored author's decisions regarding the designs of borehole charges, the formation of outcrops, the creation of additional reflective gaps, and vertical ledge of rocks are analyzed in this research. This process of rock destruction with the change of the charge of explosives in the boreholes ranges is considered from the second or third - to the first.

The research methodology includes methods of analytical calculations and geometrical constructions, geomechanical analysis of stressed rock changes in relation to the structural deformities of the ledge of rocks of different heights and lithological composition; substantiation of the simulation model of the propagation of elastic waves in anisotropic crystalline medium and the formation of waveguides in it; static analysis of mine surveyor's observations and mathematical methods for processing the results of experimental and industrial tests. Spatial-mathematical methods of solving problems and comparative assessment of their results are used.

Findings. The peculiarities and conditions of the implementation in iron ore open pit of symmetric blasting of the rock massif with complex regular structure with combined charge of explosives of modern explosives (E) are investigated. The choice of directions` formation in the blast hole network of their location is substantiated. The use of mathematical and simulation modeling, the peculiarities of formation of contours in the rock massif of maximum and minimum stressed zones around borehole charges depending on the physical, mechanical and structural characteristics of rocks as well as relative masses of various types of explosives in the combined charge are determined.

The scientific novelty consists in formulating the author's idea of symmetrical blasting of the rock, differential strain explosion, and analytical substantiation of the parameters of objects and processes for the effective implementation of the developments in the industrial work placement of open pit of ore mining and processing enterprise.

The practical significance of the research is to develop a new effective way of blasting rocks in the open pits of ore mining and processing enterprises and substantiating of the parameters of the technology of the implementation of the method, which reduces the specific costs of explosive materials and increases the profit of the MPE.

*Key words:* rock massif, explosive destruction, open pit, explosive waves, anisotropy of rocks, symmetrical action of charge of explosives;

---

### 1. Formulation of the problem

Despite the extremely numerous and serious scientific research on the effectiveness of Blasting and Explosion Works (BEW) in the open pits, the problem of the unevenness of the granulometric composition of the blasted rock, as well as the excessively high cost and environmental aggressiveness of this process clearly indicates that this problem is not completely solved. Therefore, the task of the search of the ways to avoid the mentioned negative consequences of the explosion is very relevant, as well as the increase in the effectiveness of the BEW, contributes solving the problem of rational subsurface use, resource and energy saving.

As shown by the analysis of recent studies on the theory of explosion and practice of BEW (Fokin, 2008, Bratanek, 1983), one of the least investigated theoretically and unresolved virtually questions is the uneven formation under the action of an explosion of a strained-deformed state of rock masses of a complex regular structure with acoustic anisotropy caused by it, which preferably has a periodic functional dependence (epicycloidal) of

---

\*Zhukov S.A.

E-mail address: lutsenkosergeia@ukr.net.

elastic-mechanical characteristics relative to the spatial orientation of structural dominants of rocks. The increasing effectiveness of blasting can be possible by differentiating the differential strain of the massif, optimizing the interaction between the borehole charges with the massif and between each other, and also improving the BEW technology, in particular - the methods of creating actually working additional reflective elastic waves of slits and structures of charges for this (Skachkov, 2016). In connection with this, the idea was laid for the use of a preliminary reflection slit for the formation of an additional reflective crack in the acoustically anisotropic rock massif of spatially complex forms of surfaces of various stressed states, as well as the intensification of the differential strain of the massif by explosion at the expense of specially designed multi-type charges E. To solve this problem, the research provided justification for the optimal forms of rock destruction zones around charges of explosives and the mutual arrangement of the mentioned one in the explosive network, when the charges of the first series of the boreholes (main relieving charges) are initiated only after passing through them of the direct and reflected of the slopes of the wave tip the explosion of charges of the second row, thus creating the conditions for the symmetrical action of the basic charges between the two reflective surfaces - the vertical slope of the ledge from one, and created with the short-term "back" gap – from the other.

## 2. Presentation of research material

It is known that the decrease of the rocks crushing quality with the defined structural-regularity (system cracking and blocking effect) is determined by the formation something like a waveguide due to the refraction and reflection of energy rays from the charge of E in a destructive massif on the contacts of the detached rock, as a result of which different zones of the damaged rock between the blast holes have different granulometric composition, that makes the processors to increase the mass of the explosive in the boreholes for a guaranteed reduction to acceptable levels of the "oversized" exit, at the same time inevitably getting the increased output and the redundant mass. This contradiction led the authors to the idea of finding solutions to avoid this effect by coordinating the combination of the trochoid contours of the destruction zones around the borehole charges of adjacent rows in the presence of vertical ledge of rocks and additional reflecting gaps to provide symmetric conditions work of borehole charges, purposefully designed of a combined construction.

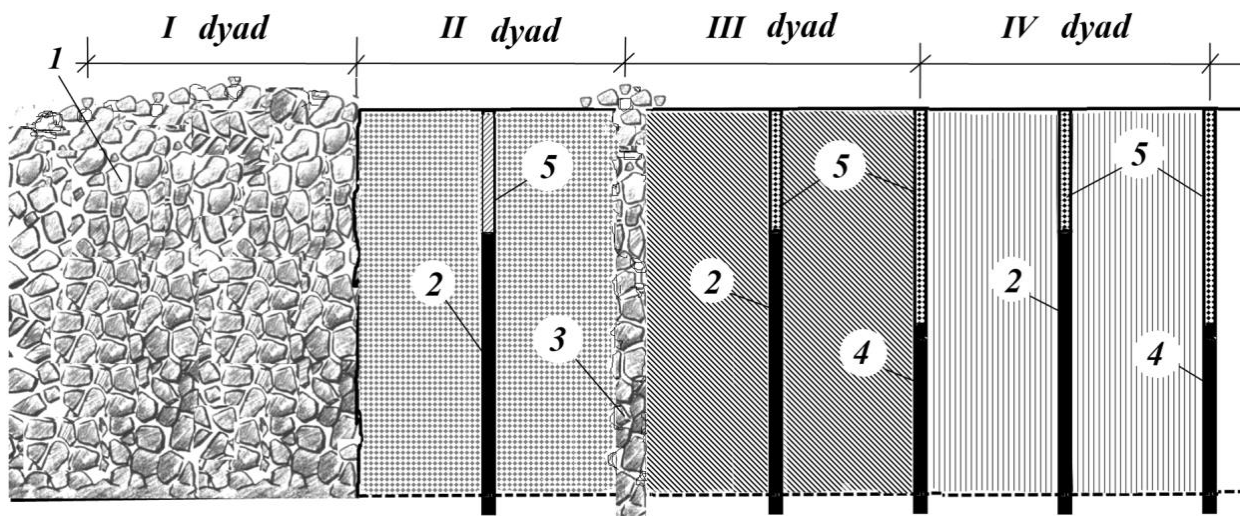


Fig. 1. Scheme of the method of differentiated energy supply of the rock massif with reverse blasting of symmetrically operating borehole charges in the vertical ledge of rocks: 1 - blasted rock; 2 - disintegration charge; 3 - reflecting gaps; 4 - combined charge of incomplete mass for formation of a reflective gap and preliminary softening of the rock

At altitudes of ledges up to 10 m, the boreholes are grouped in 2 and undermined with timing from a pair to an odd, that is, in sequence: 2nd→1nd→4th→3rd→6th→5th and so on. The application of vertical slopes in combination with the proposed sequence of charges blasting in grouped pairwise rows ensures the unification of borehole charges, and reduces by 5 ÷ 7% the specific cost of E. Under these conditions, a charge protected by a patent was used as the main one (Shapurin, 2016).

The design of the weakened charge - for the preliminary demolition of the breed and the formation of the reflecting gap - was also developed in various variants for different conditions for the implementation of the BEW (Fig. 2).



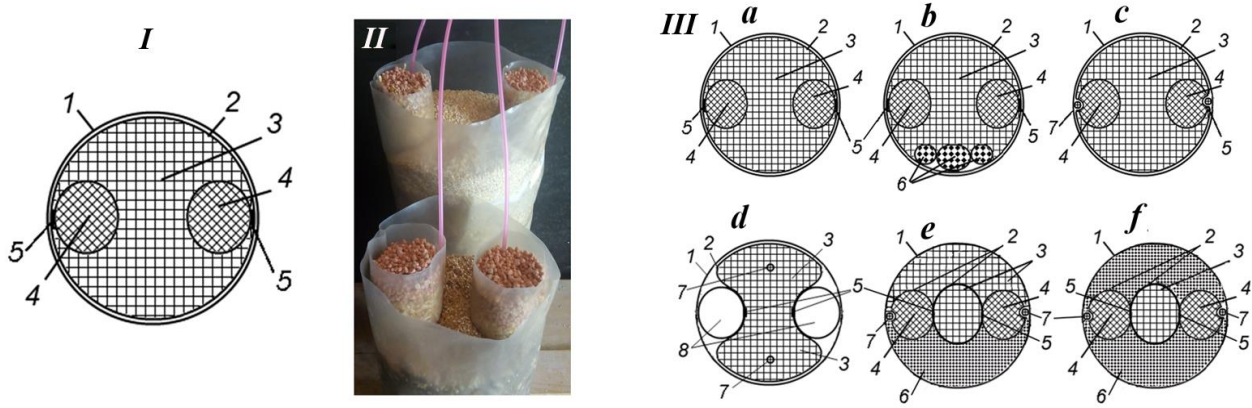


Fig. 2. Cross section of the borehole charges of the paired rows: 1 - borehole, 2 - polymer shell, 3 - low-brisant charge, 4 - linear high-brisant charges, 5 - places of penetration of the sleeve (I); full-scale specimen (II); other variants of charges (III)

The structures and substances of the main and gaps-forming charges are determined depending on the physical-mechanical characteristics of the rocks, the critical diameters of the E, the ratio of the acoustic rigidity of rock with the detonation velocity of the E, as well as the purpose and requirements for the results of the bursting of the massif.

The analysis of the BHD in relation to the open pit "Pivnichniy", where the mentioned above implementation of the differentiated-energy rocks saturation in the conditions of the dry boreholes with the simplest E - Granulite KM was carried out - showed the following. For this E, the measured values of charge density and detonation velocity are  $1020 \text{ kg/m}^3$  and  $3850 \text{ m/s}$  respectively, and the estimated heat of explosion is  $980 \text{ kcal/kg}$ . Calculated for these conditions, the value of the polytropic index ( $n$ ) is 1.8, that is within the limits typical for powdered E ( $1.5 \div 2.0$ ). The mass velocity in the Chapman-Jouguet plane ( $\omega$ , m/s) is calculated by the formula:  $\omega = v/(n+1) = 3850/(1.8+1) = 1375 \text{ m/s}$ , and the pressure of the detonation wave on the plane  $P_2 = v \cdot \omega \cdot \Delta/g = (3850 \cdot 1020)/9.81 = 5.504 \cdot 10^8 \text{ Pa}$ ,  $\omega = 1020 \text{ m/s}$ . This pressure is twice the stationary pressure in the borehole:  $P_w = 5.504 \cdot 10^8 / 2 = 2.752 \cdot 10^8 \text{ Pa}$ ; Since the charge length is 4 m and its diameter is 0.25 m, the area perceived by this pressure is  $3.61 \text{ m}^2$ . The total area of the wave from a cylindrical part and two hemispheres from the ends of the charge at the time of its release to the boundary of the crushing funnel is  $267.42 \text{ m}^2$ , that is in 74 times larger, than the original ( $3.61 \text{ m}^2$ ). Taking into account the cost of energy for the rocks destruction (for example, 20%), the pressure is about 3.0 MPa. At the same time, with the approach of the wave to the roof of a ledge, the pressure will be about 0.5 MPa, and near the scarp of a ledge - even less.

At the same time, experimental explosions with the registration of real deformations and stresses in the rock massif around the charges of E revealed somewhat lower indicators than the idealized calculations. Analyzing the stress state and structure of the massif, we established the main cause of this difference - the effect of system macrogaps that divide the rock massif into separate blocks. And after performing a comparative analysis of the values of the above mentioned deviations with the values of the gaps opening, they developed a simplified method of compensating for it in calculations by introducing the corresponding coefficient  $K_{sb}$ , which differs from the proposed in (Zhukov) in that, it takes into account not only the level of filling gaps with mineral smalls, but also the kinetics of the explosion and the inertial factor of passing an elastic wave through a macrogap. The physical meaning of this coefficient is in the "stepped" cutting of the amplitude of the elastic wave when it is extended through the blocks or layers of the rock (Fig. 3), in combination with plastic deformations of near-surface zones of macrogaps caused by the movement of rock masses when considering the behavior of the collapses rock massif as a set of elastic rods.

Taking into account these factors, we propose to determine this coefficient within the zones of intense explosive loads as,

$$K_g = \sqrt{f \cdot \rho_g} \left( 1 - \frac{r_{f.w} \cdot g_g}{A} \right)^{(1-\rho_g)} \quad (1)$$

where  $f$  - strength of the breed;  $\rho_g$  - the level of filling of the gap by the small rock, is determined by the ratio of the volume of filler  $V_3$  to the volume of the crack  $V_g$  ( $\rho_g = V_3/V_g$ );  $r_{f.w}$  - distance from charge to wave front;  $g_g$  - the index of specific fracture of the massif, is determined by the ratio of the average width of systemic gaps, normal with respect to the direction of the waves motion ( $g_g = \delta_g/l_g$ ).

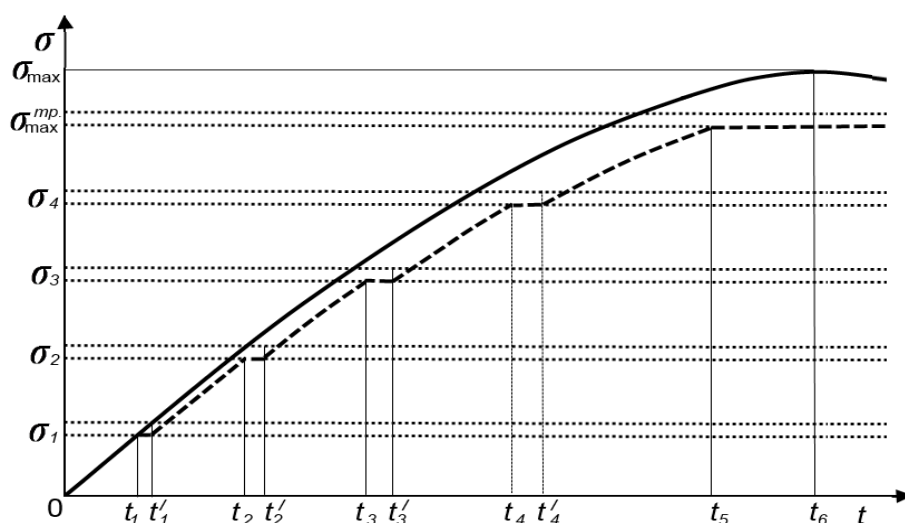


Fig. 3. Modification of the graph of stress (deformation) dependence at the front of an elastic wave under systemic rock jointing of the rock massif

Calculated values of  $K_g$  for different breeds and structural characteristics of their massifs are shown in Table 1.

Table 1. Coefficient value  $K_g$

The name of the rock	Average width of cracks, m	Average distance between cracks, m			
		0,5	1	1,5	2
Granite $A_o = 2,5 \cdot 10^{-2} \text{ m}$ , $\nu = 0,5$	0,001	0,96	0,97	0,98	0,99
	0,005	0,77	0,89	0,93	0,95
	0,01	0,45	0,77	0,87	0,89
	0,02	0,01	0,45	0,69	0,77
Migmatites $A_o = 2,3 \cdot 10^{-2} \text{ m}$ , $\nu = 0,5$	0,001	0,95	0,97	0,98	0,99
	0,005	0,75	0,88	0,91	0,94
	0,01	0,36	0,75	0,86	0,88
	0,02	0,14	0,36	0,65	0,75
Amphibolitis $A_o = 2,1 \cdot 10^{-2} \text{ m}$ , $\nu = 0,5$	0,001	0,94	0,96	0,97	0,98
	0,005	0,74	0,87	0,89	0,98
	0,01	0,22	0,72	0,84	0,81
	0,02	0,10	0,22	0,61	0,72

The introduction of this coefficient significantly improves the convergence of theoretical calculations and experimental records for the determination of the interaction of the energy of the explosion with the rock massif. The calculations of the parameters of the approach to contour blasting, to our opinion, are most convenient to perform in accordance with (Matveichuk, 2002), adding in them the spatial-energy indexes by the developed coefficient  $K_{st}$ .

From Fig. 3 it is seen how different theoretical and real, represented by the modified curve, graphs of development of stresses (deformations) at the front of the elastic wave due to the rock jointing system of the rock massif. Accordingly, the boundaries of the zones of minimum and maximum loads of a block rock massif are proposed to be determined not by a theoretical but by a modified trochoid.

As for the experimental registrations of the loading levels of rock massif in parallel ( $R_{\parallel}$ ) and perpendicular ( $R_{\perp}$ ) of subthorogonal system rock jointing of rocks, they clearly demonstrated how different stress fields are formed, depending on the degree of cleavage of system cracks and caused this acoustic anisotropy of the massif (Fig. 4): in the cemented by the mineral materials of transverse and incompatible closed longitudinal (*a*), which are close by the elasticity to the rock, and “fractured cracks” of both systems (*b*).

The nature of the influence of the structural parameters of the combined charge of E on the relationship between the relative boundaries of the parallel loading zones of the rock massif in parallel ( $R_{\parallel}$ ) and perpendicular ( $R_{\perp}$ ) subthorogonal systemic rock jointing from the ratio of masses of high-brisant ( $M_{hb}$ ) and low-brisant ( $M_{lb}$ ) charge E (Fig. 6).

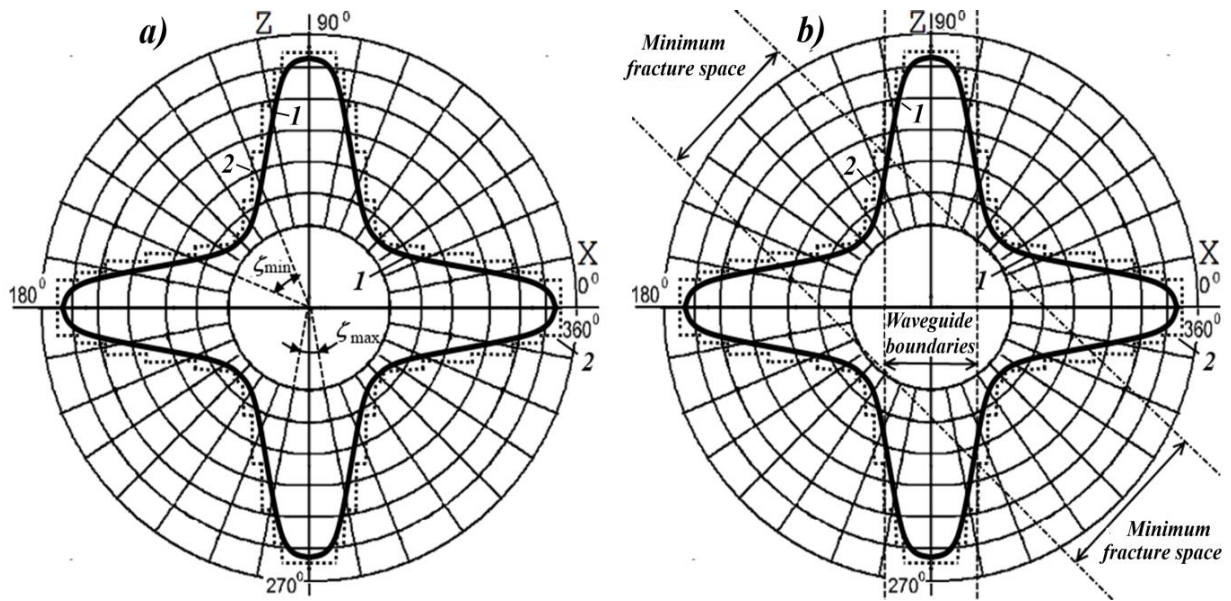


Fig. 4. Limits zones of optimum and maximum loads of a block rock mass by an explosive wave: 1 – theoretical trochoid, 2 – modified trochoid

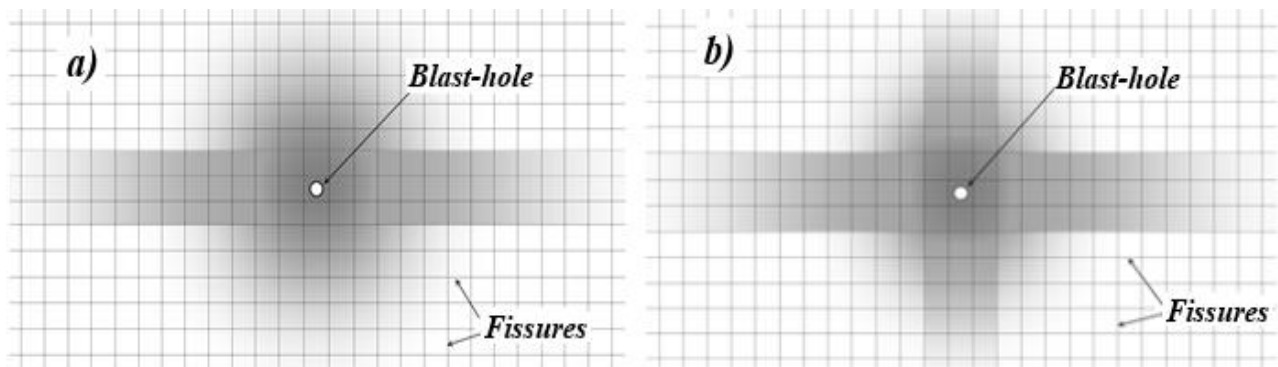


Fig. 5. The difference between the spatial loading of the rock massif around the borehole charge in dependence on the degree of clustering of systemic gaps

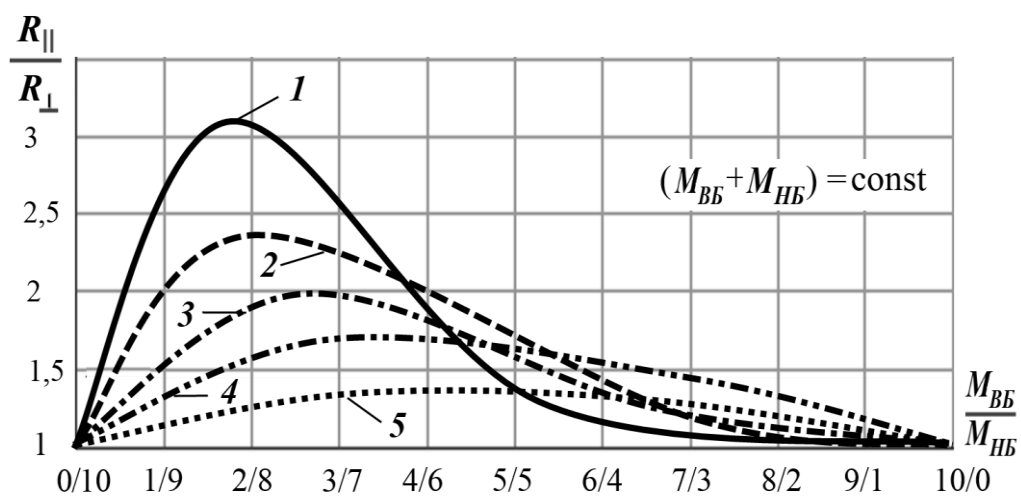


Fig. 6. Relationship between the relative boundaries of the areas of the equal loading of the rock massif in parallel ( $R_{||}$ ) and perpendicular ( $R_{\perp}$ ) to the subthorogonal systemic rock jointing from the ratio of masses of high-briant ( $M_{hb}$ ) and low-briant ( $M_{lb}$ ) charge.

### 3. Conclusions

The described above facts convince that for the ledges up to 11 m, the division of rows into groups, two in each, a significant reduction in the mass of charges in dual rows, the division of charges in the group into separate series and the beginning of the initiation of each series, namely, from the reduced by weight of charges, forcing these reduced charges give all the energy to the formation of a shielding gap, the development of defective rock of microcracks, the formation of reflected waves from free surfaces, overcoming the inertia of the massif, that is together makes easier the work of crushing rocks with the main charges in odd rows, decreasing the overall cost of E and, consequently, increases the effectiveness of E charges.

### References

- Fokin, V.A., Tarasov, G.E., Toginov, M.B., Danilkin, A.A., Shitov, Y.A., *Improving the technology of drilling and blasting operations on the limiting contour of the open pit*, Apatity, (2008).
- Bratanek, I., Woda, J., *Contouring explosion in mining and construction*, Moscow, (1983).
- Skachkov, A.A., Sergienko, S.E., Shapurin, O.V., Sidorenko, V.D., *Method of carrying out blasting operations*, Patent Ukraine UAN<sup>o</sup> 112654, U МПІК (2016.12), F42 Д 3/04, on application u 2016 06409, applied 13.06.2016 y. Date of issue 26.12.2016 y. Bull. № 24.
- Shapurin, O.V., Skachkov, A.A., Myasnikov, A.F., Myasnikov, O.F., *Blast borehole*, Patent Ukraine, UAN<sup>o</sup> 112654, U МПІК (2016.12), F42 Д 3/04, on application u 2016 06409, applied 13.06.2016y. Date of issue 26.12.2016 y. Bull. № 24.
- Zhukov, S.A., *Development of mining technology of natural stone as a source of raw materials in active open pits*, Dissertation for the degree of Doctor of Technical Sciences, Kryvyi Rih, (1998).
- Matveichuk, V.V., Chursilov, V.P., *Explosive work*, Moscow, (2002).

## Characterization and classification of andesites of Criscior and Albini from southern Apuseni Mountains, for capitalization

Danciu Ciprian<sup>a\*</sup>, Toderaș Mihaela<sup>a</sup>, Lorinț Csaba<sup>a</sup>, Florea Adrian<sup>a</sup>

<sup>a</sup>University of Petroșani, Universității Street, No.20, Petroșani, Romania

---

### Abstract

The use of rocks in construction is governed by standards that require a series of chemical criteria, mineralogical-petrographic and physical-mechanical that they must meet. The execution of various works is permitted only if they fall within certain quality criteria. In this context, the geo-mechanical properties were determined for Criscior and Albini andesites, which were compared with the conditions of admissibility imposed by current standards, for use in different areas. To get a more detailed view of geo-mechanical properties of the Criscior and Albini andesites it was required a classification based on three criteria: chemical, geological and geo-mechanical. The chemical criterion of intact rock classification considers the content of SiO<sub>2</sub> and alkali-aggregate reaction. From the geological point of view, there were chosen for classification purposes those features that could provide information on strength and deformation behavior. The geo-mechanical classification criterion employed in this paper was in accordance with standards widely used today, trying to characterize the analyzed andesites in terms of physical characteristics, strength and deformation.

*Keywords:* andesites, aggregate, chemical, geological, strenght, classification;

---

### 1. Introduction

Rocks were used as building materials since antiquity. Over time, their use in various forms, all over the world, has increased, varying by culture and time (Danciu, 2010; Danciu and Buia 2013, 2016). Raw materials like andesites, from Southern Apuseni Mountains, were used for manufacturing different types of tools since the Early Neolithic (Lorinț and Bărbat, 2014). In Romania, useful rocks are widespread in vorland structures, especially in Carpathian structures. They have multiple uses in constructions, and various other industries. Thus, besides being used as raw stone in constructions, roads and other engineering works, they can be used in ornamental-decorative works, depending on the physical-mechanical and aesthetic properties (Danciu and Buia 2016). This wide range of uses makes very important knowing the places which contain fields which are not exploited so far but whose reserves allow operation in the short run. The construction, rehabilitation and maintenance of road and rail infrastructure sectors implies the use of large amounts of materials, among which the natural aggregates have the largest share. Thus, the rigorous determination of rock qualities where the aggregates, for the above mentioned domains, is absolutely necessary and well-defined periodicity (Danciu and Buia 2013). Using rocks in the execution of various works is allowed only if they meet certain quality criteria. In this context, this study aims to establish the chemistry, mineralogy and geomechanical parameters of andesites from Southern Apuseni Mountains, in order to exploit them for the construction, rehabilitation and maintenance of road and rail infrastructure sectors. The results will be classified and compared to the limit values set by standards.

### 2. Mineralogical and petrographic study

Andesites from Criscior and Albini were previously analyzed both macroscopically and microscopically to determine the mineralogical-petrographic characteristics (Danciu and Buia 2016).

The mineralogical-petrographic study was based on analysis of thin sections using a polarizing microscope. After the macroscopic and microscopic examinations a detailed description of these rocks was possible.

---

\* Corresponding author. Tel.: +40 726 351 238; fax: +40 254 543 491.  
E-mail address: danciu\_ciprian@yahoo.com



### 2.1. Criscior Andesite - sample No.1

Sampling location: Criscior, Hunedoara district. Geologic structure: tardive subsequent magmatism (neogenic), second cycle. Rock type: magmatic, effusive (neovolcanic), neutral. Structure: semi-crystalline (hypocrystalline), porphyry-vitreous. Texture: unoriented (massive), compact. Color: dark gray. Mineralogical composition: neutral plagioclase feldspar, hornblende, microlitic vitreous paste, opaque minerals, secondary minerals (kaolinite, sericite, limonite). Plagioclase feldspar (30.5%) is represented by idiomorphic and hipidiomorphic crystals with incipient alteration stages. The plagioclase feldspar appears mostly zoned, with crystals dimensions varying between 0.3/0.2 mm and 2.0/1.0 mm. Central zones of the plagioclase feldspar, with higher anortite content, appear sometimes transformed into kaolinite and sericite. For most of the cases, the microlitic plagioclase feldspar appears not-altered. Hornblende (4.5%) appears with the rock mass as hipidiomorphic crystals, with dimensions below 1 mm. For most of the cases, the crystals contours are opacitized; sometimes, the amphibole is completely transformed into a secondary product through oxy-hydration. The vitreousmicrolitic paste (55%) in this rock type consists of amorphous volcanic glass, where the feldspars microlites appear nonuniformly distributed. As the feldspars, microlites are predominant, the resulting macroscopic color is dark gray. Reaction to acids: none of the rock components reacts with dilute HCl. Denomination rock: vitreous-porphyry Andesite (Toderaş et al., 2017).

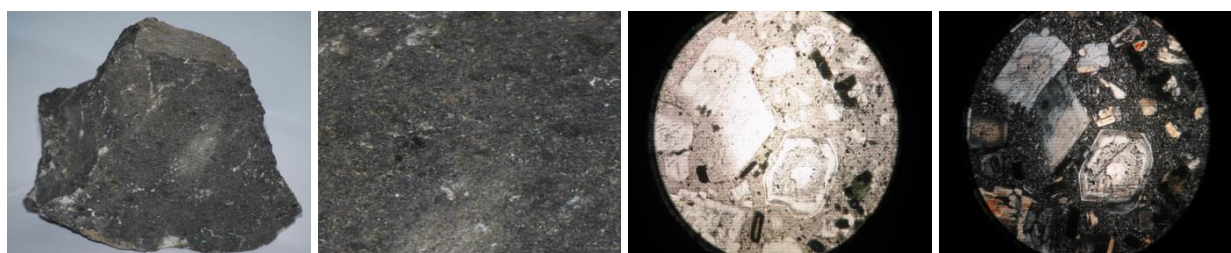


Fig. 1. Criscior Andesite

### 2.2. Albini Andesite - sample No. 2

Sample location: Albinii-Haneş, Alba District. Geologic structure: neogenic eruptivism of Apuseni Mountains (Metaliferi). Rock type: magmatic, effusive (neovolcanic), intermediary. Structure: hypocrySTALLINE (semicrystalline), porphyry vitreous. Texture: unoriented (massive), compact. Color: grey, slightly dotted. Plagioclase feldspar (23.8%) consists mostly of idiomorphic and hypidiomorphic crystals, rarely zoned. Plagioclase feldspar crystal dimensions vary from 0.01 mm for microlites and 6.2/4.3 mm for phenocryst. For thin sections parallel with crystallographic axis Z and presenting polysynthetic macles (twins), the unidirectional cleavage appears distinctly. Hornblende (12.6%) appears within the rock mass as idiomorphic, hypidiomorphic and xenomorphic crystals with dimensions between 0.2/0.08 mm and 10.3/1 mm.



Fig. 2. Albini Andesite

The sections are either parallel or perpendicular on crystallographic axis Z. Good cleavage appears distinctly, as bidirectional ( $124^\circ$ ) or basal sections and unidirectional for sections parallel with prismatic faces. Some of the idiomorphic and hypidiomorphic crystals present partial or total opacitization. Microlites (50%) are feldspathic, non-uniformly distributed within the volcanic glass. Opaque minerals (4.5%) are finely crystallized, idiomorphic, hipidiomorphic and xenomorphic, chaotically distributed within the rock paste and consisting of pyrite and oxidic minerals. Secondary minerals, represented by kaolinite, affect partially some plagioclase phenocrysts and microlites. Reaction to acids: none of the rock components reacts with dilute HCl. Denomination rock: Andesite with hornblende (Toderaş et al., 2017).

## 3. Methods and results

The alkali-aggregate reaction reveals the reactivity and potential harmfulness of aggregates containing one or more forms of low crystalline silica (opal, chalcedony, tridimite, cristobalite) and volcanic glass rich in silica (Danciu, 2010;

Danciu and Buia 2013, 2016). By verifying the alkali-aggregate reaction it is established the possibility of using the aggregates together with cements to mitigate or annihilate the reactivity and harmfulness. This determination is required for aggregates used to produce concretes in permanently or alternately contact with water or a wet environment (Toderas et al., 2017). The results obtained from the analysis are presented in Table 1. The chemical analysis for the two types of andesites were aimed at determining the main oxides. The results of chemical analysis are presented in Table 2.

Table 1. Mean values for alkali-aggregate reaction

Recoltation place/ Rock type	Silica concentration, Sc [mmol/dm <sup>3</sup> ]	Sodium hydroxide concentrate reduction, Re [mmol/dm <sup>3</sup> ]
Criscior/ Andesites	53,5	22,7
Albini/ Andesites	51,3	16,9

Table 2. Chemical composition of andesites from Criscior and Albini

Chemical composition Oxides			Recoltation place/ Rock type		
Recoltation place/ Rock type		Oxides	Recoltation place/ Rock type		Andesites/ Albini %
Andesites/ Criscior %	Andesites/ Albini %		Andesites/ Criscior %	Andesites/ Albini %	
SiO <sub>2</sub>	53,5	ZnO	0,0417		0,0362
Al <sub>2</sub> O <sub>3</sub>	13,4	SrO	0,141		0,130
Fe <sub>2</sub> O <sub>3</sub>	13,1	Cl	0,0184		-
MnO	0,326	Ga <sub>2</sub> O <sub>3</sub>	0,0206		0,0212
MgO	1,91	Rb <sub>2</sub> O	0,0289		0,0232
CaO	12,0	BaO	0,410		0,408
Na <sub>2</sub> O	0,696	HfO <sub>2</sub>	0,0880		-
K <sub>2</sub> O	2,46	CuO	-		0,0302
TiO <sub>2</sub>	1,19	Lu <sub>2</sub> O <sub>3</sub>	-		0,0756
P <sub>2</sub> O <sub>5</sub>	0,380	Ag <sub>2</sub> O	-		0,115
SO <sub>3</sub>	0,0483	ZnO <sub>2</sub>	-		0,0820
V <sub>2</sub> O <sub>5</sub>	0,0491	HgO	-		0,0411
Cr <sub>2</sub> O <sub>3</sub>	0,0874	Tl <sub>2</sub> O <sub>3</sub>	-		0,0618
NiO	0,0238				

Knowing the physical conditions of the rock can help developing a quantitative description and estimating its influence on strength and deformation characteristics. This can only be achieved by determining the physical characteristics. The determination of physical properties was performed in accordance with current standards (STAS, EN, EN), with the recommendations of the International Bureau of Rock Mechanics (BIMR) and the International Society of Rock Mechanics (Simrit). Methods for the determination and calculation relations are found in various specialty papers (Danciu, 2010; Danciu and Buia 2013, 2016). By determining the physical parameters, according to standards and specific procedures, there were obtained the following average values for the analyzed samples (Table 3 - 4). According to the purpose, there were determined the following resistance and deformation characteristics of the rocks: compressive breaking strength, freeze-thaw resistance, static modulus, Poisson's ratio, continuity index, remanent deformation coefficient and coefficient of heterogeneity, in Tables 5-8. The calculation methods and relations used are consistent with existing STAS and with the recommendations of the International Bureau of Rock Mechanics and International Society of Rock Mechanics, some of them are found in the literature (Danciu, 2010; Danciu and Buia 2013, 2016).

According to the purpose, there were determined the following resistance and deformation characteristics of the rocks: compressive breaking strength, freeze-thaw resistance, static modulus, Poisson's ratio, continuity index, remanent deformation coefficient and coefficient of heterogeneity, in Tables 5-8. The calculation methods and relations used are consistent with existing STAS and with the recommendations of the International Bureau of Rock Mechanics and International Society of Rock Mechanics, some of them are found in the literature (Danciu, 2010; Deere and Miller, 1966).

Table 3. Average values of the physical characteristics of andesites

Rock type / Recoltation place	Physical characteristics		Total porosity n [%]	Apparent porosity n <sub>a</sub> [%]	Pore number e	Compactness c [%]
	Specific density (real) $\rho \times 10^3$ [kg/m <sup>3</sup> ]	Apparent density (volumetric) $\rho_a \times 10^3$ [kg/m <sup>3</sup> ]				
Criscior/ Andesites	2,6558	2,6397	0,6061	0,3297	0,0060	99,3937
Albini/ Andesites	2,6931	2,6734	0,7339	0,3819	0,0073	99,2660



Table 4. Average values of the physical characteristics of andesites

Rock type / Recoltation place	Physical characteristics		Saturation coefficient, s	Natural humidity W [%]
	Water absorbtion Normal pressure [%]	Boiling [%]		
Criscior/ Andesites	1,4089	1,5315	0,9224	0,7963
Albini/ Andesites	1,1652	1,2375	0,9416	0,6404

Tabale 5. Average values of the resistance characteristics of andesites

Rock type / Recoltation place	Resistance characteristics			Softening coefficient after saturation $\eta_s$ [%]	Coefficient of softening after freeze- thaw $\eta_g$ [%]
	Uniaxial compressive breaking strength $\sigma_{rc}$ [MPa]; [N/mm <sup>2</sup> ]				
	Specimen status				
	usc.	sat.	i-d		
Criscior/ Andesites	143,538	129,774	125,297	9,565	12,715
Albini/ Andesites	142.404	1127.852	122.420	10.226	13.997

Table 6. Average values of the resistance characteristics of andesites

Rock type / Recoltation place	Resistance characteristics		
	Freeze-thaw resistance		
	Number of specimens with obvious damage	Gel coefficient μ <sub>g</sub>	Elasticity modulus decrease after 25 freeze-thaw cycles Δ [%]
Criscior/ Andesites	0	0,127	8,691
Albini/ Andesites	0	0,113	7,232

Table 7. Average values of the resistance characteristics of andesites

Rock type / Recoltation place	Resistance characteristics		Quality coefficient, C	Resistance to breakage by shock dry, $R_c$ [%]
	Wear resistance LOS ANGELES, LA [%]	DEVAL, $R_{uz}$ [%]		
Criscior/ Andesites	16,369	2,550	2,827	92,016
Albini/ Andesites	11,138	2,600	2,420	92,492

Table 8. Average values of the andesites deformation coefficients

Rock type / Recoltation place	Deformation coefficients				
	Static elasticity modulus, $E_s$ [MPa]	Static Poisson's ratio, $\mu$	Continuity index, $I_c$ [%]	Remanent deformation coefficient, $C_r$	Heterogeneity coefficient, $C_{df}$
Criscior/ Andesites	24036,94	0,223	67,352	0,003872	0,81
Albini/ Andesites	24336,23	0,233	82,086	0,002131	0,95

#### 4. Discussion

For the efficiency and success of the classification system used, it must be simple, easy to understand and apply, taking into account only significant and intrinsic parameters of rock that are most relevant in engineering (Deere and Miller, 1966). In this paper we performed a classification of andesites according to the literature (Danciu, 2010; Danciu and Buia 2016; Deere and Miller, 1966; Gercek, 2007; Ramamurthy, 2004; Toderaş, 2008) on the chemical, geological and geomechanical criteria, considering all of them having a significant influence. Depending on the chemical criterion, the rock classification was made based on the chemical composition of rocks and alkali-aggregate reaction, two important criteria in qualitative characterization of the rock.

Table 9. Chemical classification of the rocks

Chemical classification of the rocks	Rock type / Recoltation place	
	Andesite/Criscior	Andesite/Albini
SiO <sub>2</sub> content	Neutral	Neutral
Alkali-aggregate reaction	Non-reactive	Non-reactive

Table 10. The geomechanical classification of the intact rock

The geomechanical classification of the intact rock			Rock type / Recoltation place			
			Andesites/Criscior		Andesites/Albini	
Characteristics	Property	Classification value	Obtained value	Rock characterization	Obtained value	Rock characterization
Physical	Volumetric density	2,251 - 3,000	2,6397	- heavy	2,6734	- heavy
	Apparent porosity	< 1,0	0,3297	- slightly porous	0,3819	- slightly porous
	Water absorbtion at normal pressure	0,50-3,00	1,4089	- slightly absorbant	1,1652	- slightly absorbant
Resistance	Panet compressive breaking strength (1993)	60-200	143,538	- high resistance	142,404	- high resistance
	Compressive breaking strength used in Romania	120-200	143,538	- high resistance	142,404	- high resistance
	Quality coefficient (Deval method)	13-15	14,177	- very good	16,538	- excellent
	Freeze-thaw behavior	0	0	- resistant	0	- resistant
		< 0,3	0,127		0,113	
		< 25	12,715		13,997	
	Bad weather resistance	0	0	- fresh	0	- fresh
Deformation		80 - 100	90,4		89,8	
	Static elasticity modulus	20000 - 50000	24036,94	- rigid	24336,23	- rigid
	Poisson's ratio	0,2 - 0,3	0,223	- average	0,233	- average
	Deformation behavior	0,001 - 1	0,0038	- elastic behavior	0,0021	- elastic behavior
		0 - 3,125	0,810		0,95	
Resistance and deformation	Continuity coefficient	50-75	67,352	-average	82,086	- good
		75 - 90				
	Deere and Miller Monoaxial compressive breaking strength	100-200	143,538	- high resistance	142,404	- high resistance
	E <sub>s</sub> /σ <sub>c</sub> ratio (Modulus ratio)	< 200	167,460	- low	170,846	- low
	Ramamurthy and Arora Monoaxial compressive breaking strength	110 - 250	143,538	- high resistance	142,404	- high resistance
	E <sub>s</sub> /σ <sub>c</sub> ratio (Modulus ratio)	100 - 200	167,460	- average	170,896	- average

The geomechanical classification of the andesites was done according to the criteria used today vastly, the rocks being characterized by their physical, resistance and deformation characteristics. Considering the geomechanical criterion, the andesite were classified according to the properties from table 10. Based on the average values of the main physical and mechanical characteristics obtained for the rocks analyzed and compared with the conditions of eligibility, andesites are classified into one of the five admissibility classes (Table 11).

Table 11. Admissibility conditions of the rocks used for rail and road works

Characteristic	Rock class						Rock type / Recoltation place
	A	B	C	D	E	A	
	Admissibility conditions					Andesite/Criscior	
Apparent porosity at normal pressure, %, max.	1	3	5	8	10	0,3297	0,3819
Compressive strength, dry, N/mm <sup>2</sup> , min.	160	140	120	100	80	143,538	142,404
Wear Los Angeles car type, %, max.	16	18	22	25	30	16,369	11,138
Crushing compression strength, dry, %, min.	70	67	65	60	50	92,016	92,492
Freeze-thaw resistance:	3						
- Gel coefficient (μ <sub>25</sub> ) ,%, max.						0,127	0,113
- Freeze sensivity (η <sub>d25</sub> ) , %, max.						9,565	10,226

## 5. Conclusion

Analyzed andesites are compact, having a high density, resulted from the comparisson between the specific and apparent densities. The compressive breaking strength of the analyzed andesites is high, between 140-145 MPa, admissibility class B. The wear resistance has low values, while the dry crushing compressive strength has values above the ones imposed for the admissibility class A, these rocks being recommended for rails and road works. Depending on the values obtained for the gel coefficient and the softening coefficient after freeze-thaw cycles, we consider these rocks to be freeze-thaw resistant. By comparing the obtained results with the admissibility conditions, the analyzed rocks are classified in the admissibility class A. Due to the resistance to bad weather and wear, and because of the high polishing capacity, the analyzed andesites may be used in constructions, as decoration rocks inside and outside, for monuments. For larger projects, the andesite may be used as structure element. The andesite road borders are more lasting and fashionable than the ones from concrete. Also, because of acid rain intensification (due to growing pollution), the andesite replaces marble for monuments, because it lasts more and doesn't reacts with acids. The andesites from

Criscior and Albini used nowadays as aggregates for roads may extend their capitalization domains: for rail works, constructions, ornaments, monuments and for manufacturing andesite prefabricates.

## References

- Danciu, C., Buia, G., *Geomechanics*, Universitas Publishing Hause, Petrosani-Romania, 2016.
- Danciu, C., Buia, Gr., Classification and characterization of basalts of Branisca and Dobra - Romania, for capitalization, *Proceedings of the 1<sup>st</sup> International Conference on Industrial and Manufacturing Technologies (INMAT '13)*, Vouliagmeni, Athens, Greece, pp. 64-70, 14-16 May 2013.
- Danciu, C., *Magmatic geomechanics of the South Apuseni*, Universitas Publishing Hause, Petrosani-Romania, 2010.
- Deere, D.U., Miller, R.P., *Engineering classification and index properties for intact rock*, Technical Report No. AFNL-TR-65-116. Air Force Weapons Laboratory, New Mexico, 1966.
- Gercek, H., *Poisson's ratio values for rocks*, international Journal Rock Mechanics and Mining Sciences – Volume 44 Number 1 January pp.1-11, 2007.
- Lorinț C., Bărbat A.I., Andesites-a raw material used for manufacturing the millstones in the Early Neolithic From Hunedoara County, Romania. Preliminary Results, *Conference Proceedings of 14<sup>th</sup> Geoconference on Science and Technologies in Geology, Exploration and Mining*, Vol. I; Section: Geology/Applied and Environmental Geophysics/Oil and Gas Exploration, 2014.
- Ramamurthy T., *A geo-engineering classification for rock and rock masses*, International Journal of Rock Mechanics and Mining Sciences 4, pp.89-101, 2004.
- Toderaș M., *Tests on materialis*, Focus Publishing Hause, Petrosani-Romania, 2008.
- Toderaș, M., Moraru, R.I., Danciu, C., Buia, G., Cioca, I.L., *Model to assess the quality of magmatic rocks for reliable and sustainable constructions*, Sustainability, Volume 9, Issue 10 (October 2017), 1925, Understanding User Satisfaction Evaluation in Low Occupancy Sustainable Workplaces, 2017.

## Exploring possible accidents and recommendations for biological waste treatment installations

Nikolay Savov<sup>a</sup>, Teodora Hristova<sup>a</sup>, Petya Gencheva<sup>a</sup>

<sup>a</sup>University of Mining and Geology “St. Ivan Rilski”, Sofia, BULGARIA

---

### Abstract

In order to prevent accidents and increase the economic effect, a review of the status of the facilities operating on the territory of a bio-waste treatment plant is made. All facilities have been inspected. On the basis of the registered failures or difficulties in the control of the facilities, critical points of the technological line have been indicated. The possible cases are discussed whose decision would lead to the prevention of accidents and early decommissioning of the available systems. Such analyses are usually made after the occurrence of accidents and the accumulation of data about them; according to the authors, however, a preliminary monitoring will bring about positive economic results. The newly-opened plant has not been in operation for a long time, yet several pre-accident conditions have already been identified. As a result of erosion and corrosion processes, wear of one of the concrete surfaces has been detected in a storage area for bio-waste. Another problem is the disturbed superficial structure and plastic deformation of the front loader buckets. The causes of the erosion and corrosion processes have been analyzed and identified. Measures have been recommended to solve the problems arising from the routine activity of these facilities. Following the implementation of the proposed measures, the lifetime of the inspected facilities is expected to extend.

**Keywords:** bio-waste; compost; bio-gas; accident; repairs;

---

### 1. Introduction

Environmental pollution is one of the major and most topical problems in the modern world. Its prevention depends on each and every resident of this planet. The population growth is also associated with consumption increase that has turned the issue of domestic waste into a global problem. Intelligent waste management is a multi-stage process involving public education in environmental protection, the construction of waste separation, composting, and waste disposal facilities, as well as of facilities for the transformation of wastes into material resources.

The aim of this report is to examine the reasons for the premature repairs in a newly-constructed bio-waste treatment plant. The object of the report are the premises and the adjoining facilities. The analysis of possible problems in such an enterprise will facilitate risk management.

By inspecting the likely locations for the occurrence of breakdowns and preventing them, losses will be reduced. Such an analysis is usually performed after the occurrence of breakdowns and the accumulation of data from them. Since the enterprise has been in operation for a short period of time, the study is constrained by the lack of data. Therefore, inspection is proposed to be carried out through pre-screening.

### 2. Technological line and problem analysis

The bio-waste processing plant is made up of a production block and a compost storage area that are divided into the following facilities and aggregates: production plant for the processing of food waste; installation for anaerobic decomposition, pasteurization digesters, gas system and co-generator.

## 2.1. Production facility for the processing of biological (food) waste and compost storage area.

The bio-waste treatment plant processes biodegradable waste from kitchens, catering establishments, commercial enterprises trading in food products with expired shelf life. Initially, the waste enters the waste reception and pre-treatment area (Fig. 1). In accordance with the pre-treatment delivery conditions, waste is shipped 5 days a week, 8 hours per day. The indoor reception areas provide protection against environmental influences. They are equipped with a system of exhaust air biofilters that reduces harmful emissions. The reception areas are equipped with a drainage system for collecting infiltrate released from biological (food) waste. The water is collected in a pumping pit and pumped to a buffer tank.



Fig. 1a). Concrete cell in the biological mass storage area prior to treatment and 1b) Mechanical processing of separately collected biodegradable food waste.

The mechanical processing is performed by a compact system consisting of three efficient components. A front loader loads the organic waste from a temporary storage facility into the hunning system and feeds it into a hammer mill through an auger line (Fig. 1b). This technique ensures a constant size of the organic fraction. The separation of incidental pollutants (e.g. packaging) is carried out by means of a screw conveyor that takes the above to a packing container at a fixed speed.

The shredded waste is fed to a buffer tank through a pump. The organic fine fraction is converted into a biological suspension with a solids content of about 10-15 %. Production water is added to it.

## 2.2. Possible problems in this area

The possible stops due to breakdowns in this area occur during peak load operation and due to the presence of aggressively active components which can be divided into mechanical, electro- and physico-chemical. In the area of mechanical processing, breakdowns of the hammer mill can occur because hard-to-treat packaging falls into it. This stops the facility for hours and a group of workers have to manually remove the cause of the damage. Thus, continuous inspection and repairs are required.

In the bio-waste storage area, the problems encountered are related to the corrosion of the concrete flooring (Gencheva, 2015) and of the metal reinforcement. The destruction of concrete surfaces is caused by physico-mechanical, physico-chemical, and biological factors, as well as by human activity.

The dynamic load by the machines in the storage area and by the heavy loaders has a negative and destructive (corrosion) effect. In the process of excavation the bio-mass out, friction of the load buckets is caused which further damages and wears the concrete out. On the other hand, friction with concrete brings about erosion wear and destruction of the metal of the buckets themselves. Surface destruction of the bottom walls of the storage area is also observed that occurred as a result of friction between the wall and the uncovered front edges of the buckets during the scooping of biological mass (Fig. 2.)

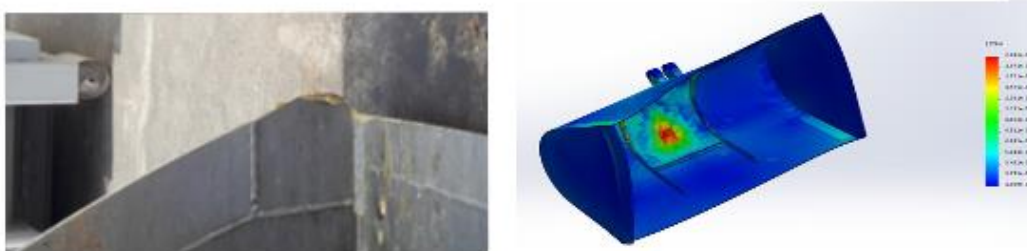


Fig. 2. Damage to the walls by the edges of the buckets and the edge of a bucket and the high tension has analysed by Solid Works programme

The rapid wear of the Liu Gong 842III front loader buckets leads to bursting bottoms and requires excessive replacement of the buckets with new ones. The causes of the plastic deformation and the destruction of metal are

mechanical. Despite the composition of the loaded food waste products, corrosion processes have not been observed so far. An analysis based on the Finite Element Method using the Solid Works Simulation software has established that the cause of the damage is the high tension that the bucket has to overcome. The calculated tension that is acceptable for a bucket with a wall thickness of 8 mm is 120 kN (2017, Minin).

$$P = 3600 \frac{N_{AB} \cdot \eta_T}{v}, N \quad (1)$$

$$P = 3600 \frac{137.0,8}{3,3} = 119563N \approx 120kN \quad (2)$$

It can be concluded that corrosion and erosion processes on the concrete surfaces and rapid wear of the buckets have been established in the storage area. The reasons are the inappropriate type of concrete flooring and the friction of loader buckets. On the basis of inspections and analyses made, the following recommendations are given:

1. A new concrete flooring in the waste storage facility has to be laid. The concrete must withstand the friction and pressure of the load-lifting machinery, as well as the impact of chemical and biologically active substances. The facilities that operate in medium to high corrosive aggressive environments, as in this case, need to be cast from corrosion-resistant concrete. On the basis of the analysis of the strength characteristics and the composition of the concrete, CEM III or CEMI I concrete is recommended with the addition of the required concentration of Pozzolite with components of microsilicium dust and treated ash from the Thermal Power Plant. The cement in the composition is recommended to be slag cement or Portland cement. The concrete should not be poured at very low or high temperatures as this will lower the cost of its application and will result in the optimum properties of the floor covering.
2. In order to determine the type of selective corrosion of the concrete flooring and the causes of its generation, it is necessary to monitor the composition and concentration of the aggressive agents present in the waste products within a certain period of time. Another requirement is to measure the highest temperature amplitudes during the seasons since the cells are not equipped with an air conditioning system.
3. It would be advisable for the concrete surfaces to be further treated with wear-resistant, antibacterial and chemically-stable coatings, which will further extend the operation period of the premises and will improve the hygiene in the storage area. Medium and high intensities of weakly aggressive liquid media are observed in the storage area and low intensity of medium and highly aggressive liquid media; therefore, a sheet waterproofing of bituminous or polymeric sheet materials (1-2 layers) is recommended. Epoxy or methyl methacrylate floorings are also suitable.
4. When laying a new concrete floor, it is necessary to work out a 5% slope. The project should provide for the implementation of a levelling layer of fine-grained concrete with an average thickness of 60 mm to form the slope of the floors. The edges between the floor and the walls, columns and foundations under the machines and the apparatus should be rounded to a radius in mm. The foundations under the machines, the apparatus, and the sills around the walls and columns with a height of at least 300 mm are protected with the same insulation as that of the floors.
5. It is necessary to build a drainage system that takes the infiltrate and the released liquids from the bio-waste to a treatment plant. In this way, the waste products will drain and will not stay stagnant and react with the floor surfaces of the storage area.
6. To reduce the friction between bucket and floor, it might be possible for either the whole or just the lower parts of the buckets to be lined with a softer material. Acid-resistant polymer material with a low aging factor and good adhesion to metal is appropriate. Laminated reinforced polymers from the group of the reactoplasts are such materials. As a result of the calculations made, it has been established that the thickness of the walls of the bucket, at its current volume, should be 4 cm to ensure the continuous and fault-free operation of the front loader, without the need for a frequent change of the bucket.

### 2.3. Anaerobic degradation process

The process of anaerobic degradation takes place in the digesters shown in Fig. 3a.

The buffer tank is used as a mixing and homogenising tank, and also as an offset buffer for those days when no waste material is supplied. The buffer tank is designed for an average stay time downtime of 3 days in order to ensure sufficient storage capacity during non-working days. The start of the process of anaerobic degradation and methane accumulation is suppressed by low temperature, aerobic atmosphere, and short residence time - up to 3 days. The suspension is pumped from the buffer tank to a digester, or bioreactor. There, the anaerobic biochemical process is carried out in several stages. Methane-forming bacteria are strictly anaerobic and sensitive to changes in pH. The suspension is assimilated in the digester, at a mesophilic temperature of about 37°C. The sequence of the processes is hydrolysis, acid formation and methane formation. The roof is designed as a flexible double-membrane roof that is stabilised with air; thus, high operational reliability is ensured.



Fig. 3. (a) Digester for anaerobic degradation and. (b) Combined heat and power station (CHPS).

#### 2.4. Possible problems in this area

The optimum operation of the reactor requires regular monitoring of the environment of bacteria. The bacteria in the reactor are highly sensitive to changes in the pH and in the temperature of the medium. Under unfavourable conditions, anaerobic bacteria cease processing the biomass and emit biogas. If any of the conditions deteriorates, the process of methanogenesis is greatly delayed and stops. In order to optimize the process of operation, we made a lot of experiments at different temperatures ( $33 \div 37^{\circ}\text{C}$ ) and we found out that the productivity grew and the biomass conditions stabilized at a temperature of  $34^{\circ}\text{C}$ . Despite the manufacturer's instructions regarding the specified operating temperature, we found out that each of the reactors had different optimum operating parameters (pH and temperature) depending on the structure and composition of the feed medium. A major problem with this type of reactor is the impossibility of servicing the mixers that homogenize the medium without breaking the airtightness. Service is required every  $3000 \div 4000$  hours, which results in process shutdowns, reactor opening, generated gas release, partial loss of biomass, etc. These technological problems lead to mechanical and electrical problems affecting the drive, such as winding or stretching and breaking of power-stirring cables. Due to improper installation, emergency servicing of the agitators had to be carried out by a diver diving into the bioreactor.

#### 2.5. Pasteurisation

After the digester, the processed biomass is heated in the pasteurisation facility in the course of one hour at a temperature of  $70^{\circ}\text{C}$ . Thereby compliance with the relevant hygiene standards (e.g. EG 1069/2009) is guaranteed. The water from the production unit, with a temperature of  $85^{\circ}\text{C}$ , is used as a heat conductor. After pasteurisation, the substrate is transported to a storage tank. The purpose of this tank is to provide storage space for the drainage process. This makes it possible for the digester to be loaded and unloaded repeatedly. The wastes that have undergone pasteurisation are transferred by means of pumps from the storage tank to the drainage stage. At this stage, separation of the substrate into streams of liquid and solid material is carried out by means of a decanter. The solid matter is transported to the maturing area and is mixed with green waste. After draining, the water is poured into a small buffer tank and is then pumped out into a processed water tank.

#### 2.6. Possible problems in this area

The main problems are technological and result from the lack of an averaging tank where the added coagulants have enough time to react with the substrate before the decanter. This will ensure homogeneity of the flow and the decanter will be able to separate the solid phase from the liquid phase with sufficient quality. The requirement is that the humidity of the waste material be up to 30%; currently, humidity exceeds 40-45%, and occasionally amounts to 60%. This causes debalancing of the decanter, leading respectively to mechanical and electrical problems and such associated with control and measuring devices and automation. and CMDA (Control-measuring devices and automation) problems.

#### 2.7. Biogas production

The biogas produced in the digesters amounts to 3,412 t/y. It is stored in the flexible membrane tank above the digester and undergoes a process of dehydration and desulfurization, both of which are additional activities. The wastes should be treated in compliance with Annex VI, Chapter II, C 12 and 13 of the European Regulation EU 1774/2002. The already purified bio-gas is fed to the co-generators, where energy is generated by gas turbines. This energy is supplied to the national electricity grid and the heat produced is employed in pasteurization as well as for everyday and other production needs on the plant.



## 2.8. Gas Engineering

For security reasons, the necessary safety devices and deflagration equipment are provided along the entire gas route. The biogas produced has a methane content of 50-65 vol. % and a calorific value of 5.0 - 6.5 kWh / Nm<sup>3</sup>. During anaerobic digestion, sulphate will be reduced to hydrogen sulphide (H<sub>2</sub>S) through biochemical reactions. Air dosing is controlled. The products obtained from oxidation, sulfur and sulfuric acid are separated by a fertilising solution. The amount of the waste solution depends on the concentration of hydrogen sulfide in the biogas and on several reaction conditions, such as the pH. The hydrogen sulphide content is highly dependent on the input raw materials. The experience in the treatment of household bio-waste and organic food waste with high concentrations of meat shows that increased concentrations of hydrogen sulphide in biogas can be achieved that reach up to 1000-2500 ppm.

## 2.9. Possible problems in this area

Hydrogen sulfide is an acidic gas with toxic properties. It may penetrate in the biogas system, thus causing corrosion in the CHPA (combined heat and power aggregate) at high concentrations. The microorganisms that decompose (digest) hydrogen sulphide live in a narrow parameter living environment; therefore, it is necessary to regularly add biomass so that the process could function as a fixed biomass reactor. Currently, there is no established methodology and control system for controlling the concentration of each type of microorganism that carries out desulfurization. The result could be the destruction of the CHPE.

## 2.10. The co-generators (CHPA)

Two biogas plants in the CHPA are installed with a power of approx. 265 kW and around 600 kW respectively (Fig.3b). The two CHPAs are designed as container units. Prior to cooling, the biogas has a relative humidity of 95-100% and a temperature of 40°C. The heat from the exhaust system is supplied to the digester and to external consumers. If the heat generated by the CHPE plant is not necessary for processing either in the biogas plant or in some of the external consumers, it will be discharged through air-cooled radiators. If, on the other hand, the CHPE facilities do not work and the stored biogas levels reach the permissible limits, the gas is burned on a torch. The facility operates independently from the CHPE and is positioned nearby.

## 2.11. Possible problems in this area

The following problems can be detected: mechanical malfunctions or failure of the sensors and of the ventilation system. A problem that has occurred in the air monitoring system or an incorrect reporting of methane quantities could bring about a CHPE accident. Biogas that has not been sufficiently enriched with methane might cause malfunction in the plant's electricity production capacities. Employees who have not been well-trained to work with CHPE would cause the decommissioning of the system. Ill-set software of the control system in automatic mode prevents the fully effective operation of the facility.

## 3. Conclusions and recommendations

After an analysis of the technological line problems encountered by different specialists, we have identified the major factors and reasons for accidents occurring before the expiry of the envisaged warranty for the operation of the facilities on the territory of the biological waste treatment plant. They are:

- technological factors;
- physico-chemical factors;
- electro-mechanical factors;
- problems with control and measuring devices and automation (CMDA problems) and SCADA problems;
- the human factor.

The influence of the individual factors is shown in Fig. 4a.

During operation, it was established that the mechanical, electrical, and CMDA problems were caused by technological errors, unfulfilled planned repairs, and personnel errors while operating the systems. Defects in sensors and executive mechanisms lead to a loss of biogas, i.e. losses by non-produced energy. The identified erosion and corrosion problems were the result of aggressive environment which was higher than the technologically planned.

To prevent the occurrence of further problems, it is necessary to:

- replace components of the machinery and equipment with such made of corrosion-resistant materials;
- install frequency inverters and compile the SCADA system;
- implement an additional sensor system and to replace part of the currently installed sensors;
- implement a flexible automatic control and monitoring system that can be further adjusted if parameter altering is required;
- train and motivate the staff.

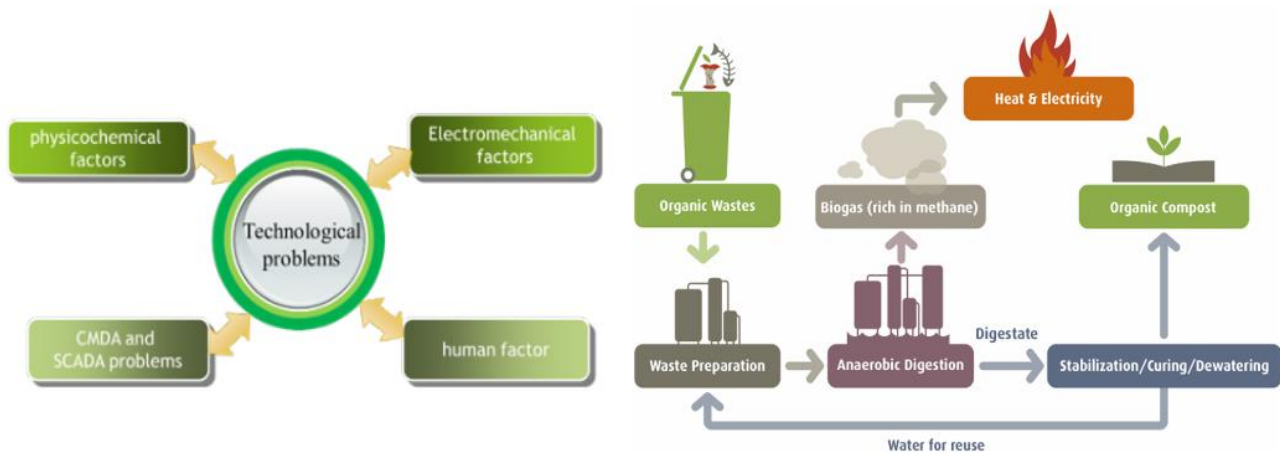


Fig. 4. (a) Factors for the occurrence of accidents and the relationship between them and (b) Technological line for waste processing

#### 4. Conclusion

Based on the analysis made, it can be concluded that the reasons for the accidents are due to an incorrect selection of the installed facilities. The selection should be made in compliance with the nature of the work, as well as with the quantity and the type of waste to be treated. The accidents are associated with the mechanical wear of the equipment, resulting in electro-mechanical damages. The low level of qualification of the staff is another problem that needs to be considered and action should be taken to improve the skills of those employed in the individual sectors. The implementation of the measures recommended will prevent decommissioning of the facilities, which will bring about positive economic results.

#### References

- Gencheva P., Recommendations for the Protection of Concrete Surfaces against Corrosion, *Annual of the University of Mining and Geology "St. Ivan Rilski "*, ISSN 1312-1820, 58, pp. 144 -148 ,(2015).
- Lilkov, V., Hydration of Cements with Mineral Additives and Structure of Hardened Cement Pastes, *Dissertation*, (2018).
- Minin, I., Simulation Computer Testing of the Loader Bucket Used in the Production of Biogas with the "SOLID WORKS SIMULATION" module, *Bulgarian Magazine for Engineering Design*, issue 31, (2017).
- Ordinance No 2 on the classification of waste WASTE MANAGEMENT LAW
- [https://www.fsai.ie/uploadedFiles/Legislation/Food\\_Legislation\\_Links/Meat\\_-\\_Fresh\\_Meat/Consol\\_Reg1774\\_2002.pdf](https://www.fsai.ie/uploadedFiles/Legislation/Food_Legislation_Links/Meat_-_Fresh_Meat/Consol_Reg1774_2002.pdf)
- <http://www.hse.gov.uk/landuseplanning/failure-rates.pdf>

## Selection of personal protective equipment for use in potentially explosive atmospheres

Florin Adrian Păun<sup>a\*</sup>, Mihaela Păraian<sup>a</sup>, Adrian Marius Jurca<sup>a</sup>, Dan Gabor<sup>a</sup>,  
Niculina Vătavu<sup>a</sup>, Cătălin Mihai Popa<sup>a</sup>

<sup>a</sup>National Institute for Research and Development in Mine Safety and Protection to Explosion – INSEMEX, 32-34 G-ral Vasile Milea street, Petroșani, 332047, Romania

---

### Abstract

Personal protective equipment worn or held by a worker to protect him against one or more of the risks that might endanger his safety and health at work, intended for use in explosive atmospheres shall be designed and manufactured in such a way that can't be the source of an arc or an electrical, electrostatic spark or results by a shock that could ignite an explosive mixture. One of the potential ignition sources for explosive mixtures is static electricity, namely electrostatic discharge from personal protective equipment (clothing, footwear, head and hand protection, etc.) and from person. The purpose of the paper is to identify and establish the criteria for the selection of personal protective equipment for use in potentially explosive atmospheres, depending on the risk factors and the classification of hazardous areas, for the purpose of ensuring a level of safety and health at work higher possible.

**Keywords:** personal protective equipment, static electricity, electrostatic discharges, explosive atmosphere.

---

### 1. Introduction

Personal protective equipment worn or held by a worker to protect him against one or more of the risks that might endanger his safety and health at work, intended for use in explosive atmospheres shall be designed and manufactured in such a way that can't be the source of an arc or an electrical, electrostatic spark or results by a shock that could ignite an explosive mixture.

Explosive mixtures may be initiated by a multitude of ignition sources, but if we refer to personal protective equipment, static electricity, more precisely electrostatic discharges, is identified as a source of ignition. Electrostatic discharge as a source of ignition of explosive mixtures may come from individual protective equipment such as clothing, footwear, head and hand protection, face and eyes, and persons.

Static electricity, as a source of electrostatic discharges, may occur in technological processes such as electrostatic painting, printing, sorting of electrostatic materials, etc., or as a random undesirable phenomenon. In general, the occurrence of static electricity or electrostatic discharges may constitute a risk, namely: fires and explosions, unexpected detonation of the electrical detonators and pyrotechnic articles, unexpected operation of sensitive control equipment, electric shock at people.

Of these risks, especially fires and/or explosions due to the initiation of explosive mixtures by electrostatic discharges, requires the application of technical or organizational measures which minimize their effects on the safety and health of workers and other persons.

In this context, it is very important to identify and establish those measures that prevent the risk of fire and / or explosion, in order to ensure the highest level of safety and health at work.

One of the necessary measures is the use of adequate personal protective equipment for the intended use area which meets the essential health and safety requirements specific to environments with risk of explosion so as to avoid the possibility of generating electrical ignition sources, mechanical or other nature. Generally, in industrial spaces where combustible/flammable substances are processed, explosive mixtures of gases, vapors, mists or dust and air may occur under normal working conditions due to processes or accidental leakages.

---

\* Corresponding author. Tel.: +40 254 541 621; fax: +40 254 546 277.  
E-mail address: florin.paun@insemex.ro.

Generally in order to reduce the risk of explosions in industrial spaces with potentially explosive atmospheres called "Ex areas", must be used personal protective equipment in special construction for potentially explosive atmospheres which can't produce or constitute sources of energy which could initiate an explosion.

It follows that the personal protective equipment used in such "Ex areas" must meet the essential safety requirements regarding to the explosions hazard by avoiding the ignition sources of explosive atmosphere such as, for example, the sources of electrostatic nature.

## **2. Safety requirements applicable to the personal protective equipment intended to use in the environments with explosion danger**

Personal protective equipment intended for use in potentially explosive atmospheres shall comply with the applicable safety and health requirements depending on the category of equipment and Ex., areas, as laid down in European Parliament Regulation (EU) 2016/425 of 9 March 2016 on personal protective equipment and repealing Council Directive 89/686/EEC.

According to requirement 2.6 of Regulation (EU) 2016/425 "PPE intended for use in potentially explosive atmospheres must be designed and manufactured in such a way that they can't be the source of an arc or spark of electrostatic nature or resulting from a shock, which could ignite an explosive mixture", (Regulation (EU) 2016/425).

Establishing the personal protective equipment compliance with applicable essential health and safety requirements suppose their assessment in relation to the performance of protection against risk factors (explosion, fire, etc.).

Regarding to the assessment of personal protective equipment from the point of view of the performance against static electricity, the requirements are found in equipment specific standards as well as in Regulation (EU) 2016/425.

In this sense, some of the standards referred to can be mentioned, namely: SR EN 1149-5:2008 Protective clothing - Electrostatic properties - Part 5: Material performance and design requirements; SR EN ISO 20344:2012 Personal protective equipment - Test methods for footwear; SR EN 420 + A1:2010 Protective gloves - General requirements and test methods.

Regarding to the requirements for the prevention of dangerous electrostatic discharges from persons, these are given in IEC 60079-32-1/TS/Ed1: Explosive atmospheres - Part 32-1: Electrostatic hazards, Guidance.

Requirements and test methods for static electricity dissipation protective clothing to avoid sparks that may cause ignition according to SR EN 1149-5:2008 are as follows:

### *2.1 Material requirements*

Electrostatic dissipating materials shall meet at least one of the following requirements:

- $t_{50\%} < 4$  s or  $S > 0,2$  when the material is tested with the second method (induction charge) specified in SR EN 1149-3, where  $t_{50\%}$  represents the charge decay time and  $S$  coefficient of protection;
- the surface resistance is  $\leq 2,5 \times 10^9 \Omega$  on at least one of the surfaces when the material is tested in accordance with SR EN 11491-1.

For materials which contain conductive wires in the shape of a grid, the distance between them must not be more than 10 mm in any direction (SR EN 1149-5, 2008).

### *2.2 Design requirements*

A static electricity dissipation protective clothing must allow for the permanent covering of all improper materials during normal use (including during bending and moving the body). If such a clothing is made of multiple layers, one of which is for example an insulating material, etc., then the outermost material shall to satisfy the requirements for the material mentioned above.

Also, a static electricity dissipation protective clothing, which follow to be used shall to correspond to the user's body conformation in accordance with SR EN 340 so as to allow the body to move with all the closures provided in accordance with the manufacturer's instructions.

Attachments from non-conductive materials such as labels, reflective tapes, etc., essential from point of view of security are allowed provided these remain permanently fixed in such a way as to avoid important separation between attachments and personal protective equipment.

Conductive parts (zips, fasteners, buttons) are permitted provided that they are adequately covered by the outer material when the clothing is worn in flammable or explosive atmospheres.

## **3. Selection of personal protective equipment for use in areas with danger of potentially explosive atmosphere**

The selection of the personal protective equipment is based on the properties of the constituent materials to provide protection against static hazardous electricity, taking into account the environmental factors, the probability to appear a charging mechanism and the ignition sensitivity of the explosive atmosphere by electrostatic discharges.

When analyzing the risks of electrostatic discharge from personal protective equipment, such as protective clothing and other PPE elements, the relevant parameter is the minimum ignition energy (MIE) of the explosive atmosphere.

The performance requirements for electrostatic dissipative protective clothing provided in SR EN 1149-5 are based on explosive atmospheres with MIE equal to or greater than the most easily flammable mixture of hydrogen in the air.

Table 1 gives some guidance regarding to the electrostatic dissipative protective clothing and other PPE necessary, recommended, or unnecessary based on global risk, which are a combination of the likelihood of an explosive atmosphere, the probability to appear a charging mechanism and sensitivity to ignition of the explosive atmosphere by electrostatic discharges, (FprCEN/TR 16832, 2014).

Where "required" or "recommended" is indicated, it refers to personal protective equipment that have a single level of protection. When "not necessary" is indicated, this means that electrostatic dissipative protective clothing or other personal protective equipment is not necessary, but also that other precautions are still required to prevent electrostatic ignition sources, especially grounding of people and other conductors.

Table 1. Requirements for electrostatic dissipative protective clothing and other PPE

Dangerous areas	Charge probability	0,016 mJ ≤ MIE ≤ 0,2 mJ	MIE > 0,2 mJ	
		Explosion groups IIB and IIC	Explosion groups IIA and IIB	Explosion groups IIIA, IIIB and IIIC
Zone 0	high	necessary	necessary	
	low			
Zone 1	high	recommended	recommended	
	low			
Zone 2	high	unnecessary	unnecessary	
	low			
Zones 20, 21 and 22	high			unnecessary
	low			

### 3.1 Selection of electrostatic dissipative protective clothing

Electrostatic dissipative protective clothing must meet the performance and design requirements specified in SR EN 1149-5 and shall represent the outer layer of clothing when worn in hazardous areas.

Underwear and fully covered by electrostatic dissipative protective clothing are not necessary to be made of electrostatic dissipative materials, as long as it does not interfere with the electrical continuity between the wearer's body and the electrostatic dissipative protective clothing, (Păun et al., 2017).

One of the minimum requirements specified in Annex II of Directive 1992/92/EEC is that "... appropriate measures should be taken to minimize the risks to workers from the physical effects of an explosion." This involves that protective clothing worn in dangerous areas must provide protection against heat and flames. The need to protect against heat and flames shall be based on the results of a risk assessment, (Directive 1999/92/EC).

An explosion produces more physical effects, including explosion waves, throwing of fragments, etc. To protect workers from the thermal effects of a possible explosion, protection against heat and flames should be incorporated into electrostatic dissipative protective clothing, (Păraian et al., 2013)

Alternatively, an ensemble may be worn, that is, the protective clothing against heat and flames is worn together with electrostatic dissipative protective clothing, in which case the electrostatic dissipative protective clothing must be the outermost layer and must cover all insulating clothing. The outer layer must also have flame propagation limiting properties, (FprCEN/TR 16832, 2014).

Although Directive 1999/92/EC may require employers to provide workers adequate protective clothing, the requirements for such clothing are specified in Regulation (EU) 2016/425 and is not necessary to bear the conformity marking for ATEX equipment, unless the clothing contains electrical or electronic components.

### 3.2 Selection of protective gloves

Wearing gloves in hazardous areas may be necessary to protect the wearer from various hazards, to protect the handled products, or to improve manual handling. If gloves are necessary for any of these reasons, then gloves must also protect against electrostatic dangers if they are worn in hazardous areas as recommended in Table 1, (FprCEN/TR 16832, 2014).

Metallic hand tools and other conductive objects that can be held in the hand and is not earthed are based on hand contact as the primary earthing means. Gloves intended for use in hazardous areas shall provide an electrical connection between the hands of the wearer and any conductive object that is held in the hand so that the resistance to the ground is within acceptable limits, (Păun et al., 2017).

Materials used to carried out palms, fingers and any areas extending over the wrist of the wearer must meet the requirements for electrostatic dissipative protection gloves specified in SR EN 16350.

### *3.3 Selection of footwear and foot protection*

Conductive and antistatic footwear as defined in SR EN ISO 20345, SR EN ISO 20346 and SR EN ISO 20347 are intended primarily to provide earthing means of personnel. In many cases, only the sole of the footwear is made of conductive or antistatic materials.

However, areas of insulating materials which form the upper part of the footwear and which may extend to the bottom of the foot in the case of boots may present an electrostatic risk if they are subjected to massive electrostatic charges. In such cases, the upper part of the footwear should be made of electrostatic dissipative materials as in the case of other elements of electrostatic dissipation clothing, (FprCEN/TR 16832, 2014).

Leg protection in the form of knee pads and tibia protectors usually wear over clothing. If the outer layers are made of textile materials, they must be electrostatic dissipative materials as well as other elements of electrostatic dissipative clothing and can be evaluated according to EN 1149-5, (Părăian et al., 2013).

## **4. Conclusions**

The generation of electrostatic charges and their accumulation on persons and on the personal protective equipment worn by them present a danger in the presence of potentially explosive atmospheres or explosive substances from point of view of their initiation by electrostatic discharges.

The explosion hazard presence of due to the initiation of explosive atmospheres or explosive substances by static electricity discharges implies and requires appropriate protective measures to prevent electrostatic discharges from persons by selection for the use of personal protective equipment, which to meet safety requirements related to the prevention of ignition sources (static electricity), to which is added the provision of ways to dissipate the charges to the ground.

## **Acknowledgements**

This paper was developed within the Nucleu - Programme, carried out with the support of MCI, project no. PN 18 17 01 01.

## **References**

- Părăian, M., et al., *Guidance for the assessment of plant and personal protective equipment regarding the explosion risk in areas with potentially explosive atmospheres*, Publishing House INSEMEX, ISBN 978-973-88650-1-3, (2013);
- Păun, F., et al., *Research on explosion risk generated by static electricity in the presence of explosive atmospheres*, contract PN 16-43-02-14 (2017);
- \*\*\* Regulation (EU) 2016/425 of the European Parliament and of the Council of 9 March 2016 on personal protective equipment and repealing Council Directive 89/686/EEC;
- \*\*\* Directive 1999/92/EC on minimum requirements for improving the safety and health protection of workers potentially at risk from explosive atmospheres OJ No. L 023, 2000-01-28;
- \*\*\* SR EN 1149-5:2008, Protective clothing - Electrostatic properties - Part 5: Material performance and design requirements;
- \*\*\* FprCEN/TR 16832:2014, *Selection, use and maintenance of personal protective equipment for the prevention of electrostatic risks in hazardous areas (explosion hazards)*.

## Study of explosive characteristics of combustible powders

Cătălin Mihai Popa<sup>a\*</sup>, Silviu Marin Nan<sup>a</sup>, Mihaela Părăian<sup>a</sup>, Adrian Marius Jurca<sup>a</sup>,  
Florin Adrian Păun<sup>a</sup>, Leonard Lupu<sup>a</sup>, Niculina Vătavu<sup>a</sup>, Dan Gabor<sup>a</sup>

<sup>a</sup>National Institute for Research and Development in Mine Safety and Protection to Explosion – INSEMEX, 32-34 G-ral Vasile Milea street, Petroșani, 332047, Romania

### Abstract

Due to the continuous technical and economic development of the human society, a large number of chemical substances and compounds in the form of combustible dusts and powders are increasingly being used in the technological processes present in various industrial branches. These combustible powders, during their production, handling and storage operations, in combination with air, may lead to potentially explosive atmospheres.

The presence of combustible powders and dusts, and possibly the appearance of potentially explosive atmospheres, has led to the need to adopt and enforce protective measures to ensure an acceptable level of protection in accordance with current rules, protective measures materialized mainly through use within locations endangered by the presence of potentially explosive atmospheres of properly protected technical equipment so as to reduce the possibility of ignition of the surrounding explosive atmosphere.

Therefore, in order to be able to establish with certainty the requirements of the technical equipment that can be used in potentially explosive atmospheres generated by the fuel / air mixture, it is necessary to know the type of dust, as well as a series of parameters defining its sensitivity to ignition with different sources and the severity of the explosion it can generate, parameters known as explosive characteristics

The paper highlights the explosive characteristics of combustible powders, the methods and equipment necessary to carry out experimental tests to determine these characteristics.

**Keywords:** combustible dusts, potentially explosive atmospheres, explosive characteristics, explosion protection.

### 1. Introduction

Due to the continuous technical and economic development of the human society, a large number of chemical substances and compounds in the form of combustible dusts and powders are increasingly being used in the technological processes present in various industrial branches. These combustible powders, during their production, handling and storage operations, in combination with air, may lead to potentially explosive atmospheres.

In Figure 1 is shown the variety of industrial branches in which there are present combustible dusts from the technological processes specific to each domain (A. Jurca ș.a., 2014).

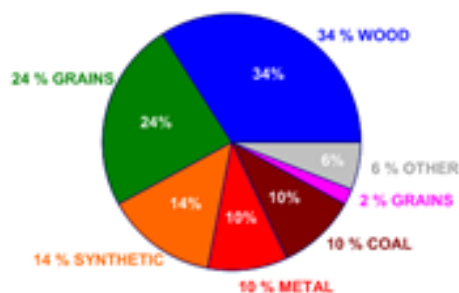


Fig. 1 – Variety of combustible dust in industry

\* Corresponding author. Tel.: +40 254 541 621; fax: +40 254 546 277.  
E-mail address: mihai.popa@insemex.ro.



For particulate solids (powders, flours, various powders, etc.) to be safely handled, it is absolutely essential to know the characteristics that influence security, including those that define the flammability and explosiveness of the powders. Also, knowing the explosive characteristics of combustible dusts is particularly important for choosing the technical equipment to be used at the work points endangered by the presence of potentially explosive atmospheres generated by these combustible powders, in order to adopt and apply protective measures to ensure an acceptable level of protection in accordance with the rules in force so as to minimize the possibility of ignition of the surrounding explosive atmosphere.

It is well known that an explosion may occur if the dust / fuel powder is present in suspension in admixture with air (with sufficient oxygen) within the explosive limits, corroborated with the existence of a source of initiation with sufficient ignition energy, and the pentagon can be defined the explosion shown in Figure 2.



Fig. 2 – Pentagon of ignition to combustible dusts

The mechanism underlying the explosion of the dust / air mixture can be explained by a chain reaction as follows: the heat of the ignition source comes into contact with the suspended particulate matter, produces its heating which results in the release of some substances chemical gases such as hydrogen, methane, ethane, etc. These combustible gases, in admixture with the air, form at one time an explosive mixture which, in contact with the source of ignition, ignites and creates conditions of heating the neighboring particles, this time, with a higher volume. This reaction is repeated from near to near the entire volume in which the powder is suspended.

The paper, in essence, presents the explosive characteristics of combustible powders, the methods and the equipment necessary to carry out the experimental tests for the determination of these characteristics under laboratory conditions, as well as the interpretation of the results obtained from the laboratory tests.

The current paper is given by the increasing importance of national and international levels to ensure a high level of occupational health and safety at workplaces where dust particles and combustible dust are produced, handled and stored.

## 2. Characteristics of combustible preparations which may produce an explosive atmosphere

In order to identify the existing explosion hazard in a space where a potentially explosive atmosphere generated by the dust / air mixture is present, the properties of the combustible dusts / powders and their safety characteristics must be known. The security features describing the relevant safety properties of combustible dust / powders are:

- a) LEL lower explosion limit, UEL upper explosion limit;
- b) LOC limiting oxygen concentration;
- c)  $p_{max}$  maximum explosion pressure
- d)  $dp/dt_{max}$  maximum rate of explosion pressure rise;
- e) MESH maximum experimental safe gap;
- f) MIE minimum ignition energy;
- g) Minimum ignition temperature of an explosive atmosphere;
- h) Minimum ignition temperature of a dust layer;

It is necessary to specify that the limits of explosivity and the limit concentration of oxygen define the combustion properties of combustible dusts / powders, while the maximum explosion pressure, the maximum explosion pressure increase velocity and the maximum experimental experimental gap define the explosion behavior theirs. Also, in order to identify the hazards of ignition, the ignition properties of an explosive atmosphere must be determined, namely: minimum ignition energy, minimum ignition temperature of an explosive atmosphere and minimum ignition temperature of a dust layer.

### 2.1. Explosion limits

Each dust / fuel powder has a lower explosion limit (LEL) and a higher explosion limit (UEL) and only mixtures within these limits can be initiated by a source of ignition.

In the case of dust and combustible dust, the lower explosion limit is approximately 20 to 60 g/m<sup>3</sup> of air, and the upper explosion limit is approximately 2 to 6 kg/m<sup>3</sup> of air. Explosion limits for dusts, compared to gas explosion limits, do not have the same meaning, as dust clouds are generally not homogeneous, in which case dust concentration can fluctuate a lot due to dust and dispersion in the atmosphere. Due to this, where there are deposits of fuel dust, it is always necessary to consider the possibility of forming a potentially explosive atmosphere.

## 2.2. Oxygen Limit Concentration (LOC)

Oxygen Limit Concentration (LOC) is the maximum oxygen concentration in a dust / air / inert gas mixture at which an explosion can not occur under the specified test conditions.

## 2.3. Maximum Explosion Pressure ( $p_{max}$ )

Maximum Explosion Pressure ( $p_{max}$ ) is the maximum value of the pressure occurring during the explosion of a dust / air mixture at the optimum concentration in a closed container determined under the specified test conditions (SR EN 14034-1, 2011).

## 2.4. Maximum Explosion Pressure Speed ( $(dp / dt)_{max}$ )

Maximum Explosion Pressure Speed ( $(dp / dt)_{max}$ ) is the maximum increase in pressure per unit time in a closed container during an explosion of an atmosphere determined under the specified test conditions (SR EN 14034-2, 2011).

## 2.5. Minimum ignition energy MIE or $E_{min}$

Minimum ignition energy MIE or  $E_{min}$  is lowest electrical energy stored in a capacitor which upon discharge is sufficient to effect ignition of the most sensitive dust/air mixture under specified test conditions (SR EN ISO/IEC 80079-20-2, 2016).

## 2.6. Minimum ignition temperature of a dust cloud

Minimum ignition temperature of a dust cloud is defined as the lowest temperature of the hot surface on which the most ignitable mixture of the dust with air is ignited under specified test conditions (SR EN ISO/IEC 80079-20-2, 2016).

## 2.7. Minimum ignition temperature of a dust layer

Minimum ignition temperature of a dust layer is the lowest temperature of a hot surface at which ignition occurs in a dust layer under specified test conditions (SR EN ISO/IEC 80079-20-2, 2016).

The specific constriction of dust ( $k_{st}$ ) is also called the explosion index and represents the independent volume characteristic determined by the use of the following cubic equation:

$$(dp / dt)_{max} \cdot V^{1/3} = \text{const.} = K_{st} = K_{max}. \quad (1)$$

Depending on the determined value, dust can be classified in the following classes.

Table 1. Characterization of dust according to the explosion index value

Dust explosion index	$K_{st}$ [ m · bar/s ]	Characterization
St 0	0	No explosion
St 1	$> 0 \div 200$	Poor explosion
St 2	$> 200 \div 300$	Strong explosion
St 3	$> 300$	Extreme explosion

## 3. Methods for the determination of the combustibility powder explosivity characteristics

In order to determine the explosive characteristics of combustible dusts / dusts, a series of standards have been developed and implemented at European level which present the methods that can be applied and the equipment required for this. These standards were taken over as Romanian standards by INCD INSEMEX Petrosani:

**SR EN 14034-1+A1:2011** – Determination of explosion characteristics of dust clouds.

Part 1: Determination of maximum explosion pressure -  $p_{max}$ ;

**SR EN 14034-2+A1:2011**– Determination of explosion characteristics of dust clouds.

Part 2: Determination of the maximum rate of explosion pressure increase –  $(dp/dt)_{\max}$  ;

**SR EN 14034-3+A1:2011**– Determination of explosion characteristics of dust clouds.

Part 3: Determination of lower explosion limit LEL for dust clouds;

**SR EN 14034-4+A1:2011**– Determination of explosion characteristics of dust clouds.

Part 4: Determination of the CLO oxygen concentration limit of dust clouds;

**SR EN 50281-2-1:2003/AC:2013** – Electrical apparatus intended for use in the presence of combustible dust.

Part 2-1: Test methods. Methods for determining the minimum ignition temperature of the dust

**SR EN ISO/IEC 80079-20-2:2016** - Explosive atmospheres.

Part 20-2: Product features. Test methods for combustible dusts.

#### 4. Apparatus for determining the explosion characteristics of combustible powder

To determine the explosive parameters for combustible dust / powder, one of the apparatus used is KSEP-20. This apparatus consists of an explosion-proof spherical blast-furnace made of stainless steel with a volume of 20 dm<sup>3</sup> - Figure 3. A water jacket has the role of absorbing the heat produced by the explosions. To perform the test, the dust to be analyzed is dispersed within the sphere of the pressure dust receptacle through a quick acting valve and a dispersing nozzle. The quick acting valve is pneumatically opened and closed by an auxiliary piston. The compressed air valves are electrically activated. The ignition source is located in the center of the sphere.

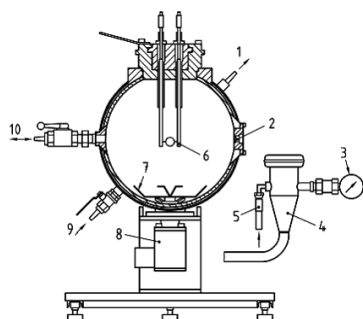


Fig. 3 – The KSEP-20 test facility

##### The legend:

- |   |  |
|---|--|
| 1 Water outlet                          | 6 Ignition source                          |
| 2 Pressure transducers                  | 7 Spray nozzle                             |
| 3 Manometer                             | 8 Quick-acting valve                       |
| 4 Dust container (0.6 dm <sup>3</sup> ) | 9 Inlet for water                          |
| 5 Air intake opening                    | 10 Exhaust outlet (air, reaction products) |

Depending on the parameter to be determined, the commands to the test facility are transmitted using an interface and a dedicated software. Two piezoelectric pressure transducers are recorded on the inner wall of the explosion vessel recording variations in the pressure of the explosion produced inside the vessel. After the test, the data obtained using this software is collected, generating based on recorded data the graphs necessary for the evaluation of the explosive parameters (Jurca A. ș.a 2007).

Figure 4 illustrates how the graphs are collected and generated based on data collected through the specialized software for Niacin USP (Nicotinic acid), the chemical formula of which is C<sub>6</sub>H<sub>5</sub>NO<sub>2</sub>.

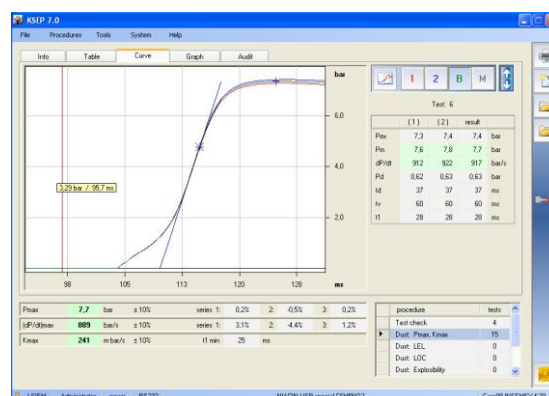
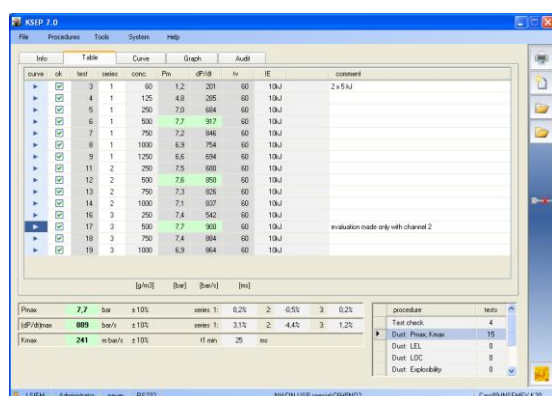


Fig. 4 - Integrated collection system of results

In this case, the following explosive parameters were determined:

- maximum explosion pressure -  $p_{\max}$  [bar];
- maximum rate of explosion pressure increase -  $(dp/dt)_{\max}$  [bar/s];

Following the tests, the results presented in table no. 2 for series of dust samples at different concentrations of Niacin fuel USP (Nicotinic acid) –  $C_6H_5NO_2$

Table 2. Test results

Test	Serie	Concentration of dust [g/m <sup>3</sup> ]	$p_m$ [bar]	$dp/dt$ [bar/s]
1	1	60	1.2	201
2	1	125	4.8	285
3	1	250	7.0	684
4	1	500	<b>7.7</b>	<b>917</b>
5	1	750	7.2	846
6	1	1000	6.9	754
7	1	1250	6.6	694
8	2	250	7.5	680
9	2	500	<b>7.6</b>	<b>850</b>
10	2	750	7.3	826
11	2	1000	7.1	837
12	3	250	7.4	542
13	3	500	<b>7.7</b>	<b>900</b>
14	3	750	7.4	884
15	3	1000	6.9	864

Explosive indexes  $p_{\max}$  and  $(dp/dt)_{\max}$  are defined as the average of the maximum values obtained for each series of tests (total 3 series) (SR EN 14034-1, SR EN 14034-2).

Subsequently, the  $K_{\max}$  explosion index is calculated by  $(dp/dt)_{\max}$ .

$$p_m [\text{for 3 series}] = \text{the maximum value in each series;} \quad (2)$$

$$p_{\max} = (p_m [\text{series 1}] + p_m [\text{series 2}] + p_m [\text{series 3}]) / 3; \quad (3)$$

$$p_{\max} = 7,66 [\text{bar}] \quad (4)$$

$$(dp/dt)_m [\text{for 3 series}] = \text{the maximum value in each series;} \quad (5)$$

$$(dp/dt)_{\max} = (dp/dt [\text{series 1}] + dp/dt [\text{series 2}] + dp/dt [\text{series 3}]) / 3 \quad (6)$$

$$(dp/dt)_{\max} = 889 [\text{bar/s}] \quad (7)$$

Taking into account the cubic law presented as well as the value of the volume in which the tests  $V = 0.02\text{m}^3$  are obtained, it results :

$$V^{1/3} = 0,02^{1/3} = 0,27144 \quad (8)$$

$$(dp/dt)_{\max} \times V^{1/3} = \text{const} = K_{St} \quad (9)$$

$$K_{\max} = 0,27144 \times (dp/dt)_{\max} = 0,27144 \times 889 = 241,3 [\text{bar m/s}]. \quad (10)$$

Taking into account the result obtained as well as the classification shown in Table 1, the explosive index for the tested Niacin USP (Nicotinic acid) –  $C_6H_5NO_2$  - St 2 (strong explosion).

## 5. Conclusions

In industrial production processes where combustible powders / dusts are present, it is of great importance to know their explosive characteristics in order to be able to accurately determine whether or not they are explosive and implicitly whether their processing, handling and storage may lead to the emergence of potentially explosive atmospheres.

The determination and interpretation of explosive characteristics of combustible dusts / powders is of paramount importance in the primary phase of the explosion risk assessment as well as the adoption and application of protective measures ensuring an acceptable level of protection in accordance with the rules in force , protective measures materialized primarily in the use of properly protected equipment in locations at risk from the presence of potentially explosive atmospheres so as to reduce the possibility of ignition of the surrounding explosive atmosphere.

## Acknowledgements

This paper was developed within the Nucleu - Programme, carried out with the support of MCI, project no. PN 18 17 02 01.

## References

- Jurca A., Ghicioi E., Păraian M., Burian S., Darie M., Sicoi S., Păun F., *Implementation and carrying out of laboratory test stands required for conformity assessment of equipment intended for use in potentially explosive atmospheres generated by combustible dusts* - IRECEEX, INSEMEX Petroșani, (Romanian) C 43/2005.
- Jurca A., Lupu C., Păraian M., Vătavu N., Iacob-Ridzi F.T., *The importance of determining explosivity parameters of combustible dusts*, *Environmental Engineering and Management Journal*, 13, 1535-1545, (2014).
- SR EN 14034-1+A1:2011, *Determination of explosion characteristics of dust clouds - Part 1: Determination of the maximum explosion pressure  $p_{max}$  of dust clouds* (Romanian) (2011)
- SR EN 14034-2+A1:2011, *Determination of explosion characteristics of dust clouds - Part 2: Determination of the maximum rate of explosion pressure rise  $(dp/dt)_{max}$  of dust clouds* (Romanian) (2011).
- SR EN ISO/IEC 80079-20-2, *Explosive Atmosphere – Part 20-2: Material characteristics – Combustible dusts test methods* (2016).

## Research on the identification of the dangers of dust and water entering equipment for potentially explosive atmospheres

Niculina Vătavu<sup>a\*</sup>, Emilian Ghicioi<sup>a</sup>, Sorin Vătavu<sup>b</sup>, Mihaela Părăian<sup>a</sup>, Adrian Jurca<sup>a</sup>, Florin Păun<sup>a</sup>, Dan Gabor<sup>a</sup>, Mihai Popa<sup>a</sup>

<sup>a</sup>National Institute for Research and Development in Mine Safety and Protection to Explosion – INSEMEX, 32-34 G-ral Vasile Milea street, Petroșani, 332047, Romania

---

### Abstract

In order to be used safely, all electrical or non-electrical equipment operating in areas with potentially explosive atmospheres should be provided with enclosures that provide a certain degree of IP protection (International Code). According to the general standard SR EN 60079-0 in hazardous areas Ex it is necessary that an electrical / non-electrical equipment, in addition to the specific type of protection, must provide at least a standard degree of protection IP XX, the test procedures being in accordance with the requirements of SR EN 60529 and in the case of rotating electric machines according to SR EN 60034-5. The normal degree of protection is protection against access to hazardous parts inside the enclosure and protection against penetration of solid bodies and protection against water penetration inside the equipment. Tests for the determination of the first characteristic number - protection against penetration of solid bodies are particularly important for equipment intended for use in hazardous areas of explosive atmospheres generated by combustible dust as this protection is also a requirement for explosion protection. Within the ENExEMEIP laboratory of INCD INSEMEX, laboratory tests have been developed to verify the first characteristic figure by building a high performance dusting chamber, according to the method standardized of European standard, and purchasing a stand for checking the protection against falling water in the form of rain and against water projections, which determines the second characteristic number 3 and 4.

**Keywords:** potentially explosive atmospheres; normal protection degree; combustible dust.

---

### 1. Generality

Many types of dust that are generated, processed, handled and stored, are combustible. When ignited they can burn rapidly and with considerable explosive force if mixed with air in the appropriate proportions. It is often necessary to use electrical apparatus in locations where such combustible materials are present, and suitable precautions must therefore be taken to ensure that all such apparatus is adequately protected so as to reduce the likelihood of ignition of the external explosive atmosphere. In electrical apparatus, potential ignition sources include electrical arcs and sparks, hot surfaces and frictional sparks.

Areas where dust, flyings and fibers in air occur in dangerous quantities are classified as hazardous and are divided into three zones according to the level of risk.

Generally, electrical safety is ensured by the implementation of one of two considerations, i.e. that electrical apparatus be located where reasonably practicable outside hazardous areas, and that electrical apparatus be designed, installed and maintained in accordance with measures recommended for the area in which the apparatus is located. Combustible dust can be ignited by electrical apparatus in several ways:

- by surfaces of the apparatus that are above the minimum ignition temperature of the dust concerned. The temperature at which a type of dust ignites is a function of the properties of the dust, whether the dust is in a cloud or layer, the thickness of the layer and the geometry of the heat source;
- by arcing or sparking of electrical parts such as switches, contacts, commutators, brushes, or the like;
- by discharge of an accumulated electrostatic charge;
- by radiated energy (e.g. electromagnetic radiation);
- by mechanical sparking or frictional sparking associated with the apparatus.

---

\* Corresponding author. Tel.: +40 254 541 621; fax: +40 254 546 277.  
E-mail address: niculina.vatavu@insemex.ro.

In order to avoid ignition hazards it is necessary that:

- the temperature of surfaces on which dust can be deposited, or which would be in contact with a dust cloud, is kept below the temperature limitation specified.
- any electrical sparking parts, or parts having a temperature above the temperature limit specified.
- are contained in an enclosure which adequately prevents the ingress of dust, or
- the energy of electrical circuits is limited so as to avoid arcs, sparks or temperatures capable of igniting combustible dust;
- any other ignition sources are avoided.

## 2. Normal degree of protection provided by the enclosures of the equipment

When choosing, designing and installing electrical equipment intended for use in explosive atmospheres, besides the protective measures required (choice of anti-explosion protection, temperature class and explosion group of liquids, explosives, mists and / or dust suspensions in air or in the form of a layer), electrical installations must be protected by enclosures to ensure:

- Protect people from access to dangerous parts inside the carcass (parts moving or under voltage);
- Protection of equipment inside the enclosure against the penetration of foreign solids;
- Protection of equipment inside the enclosure against harmful effects due to water penetration.

The significance of each characteristic figure is given in Tables 1, 2 and 3 (SR EN 60529:1995 + SR EN 60529:1995/A1:2003).

Table 1. The significance of first characteristic figure

		NAME	EXPLANATIONS
FIRST CHARACTERISTICS	0	Unprotected	<ul style="list-style-type: none"> <li>• Touching the parts moving or under voltage inside the enclosure is not obstructed;</li> </ul>
	1	Protected against penetration of foreign solids larger than 50 mm	<ul style="list-style-type: none"> <li>• The penetration of foreign solids is not hindered</li> <li>• Accidental or intentional touching of internal parts under voltage or in motion, with a large surface of the human body, for example the hand, is not possible. Voluntary touch is possible;</li> <li>• Penetration of foreign solid bodies up to 50 mm in diameter is prevented</li> </ul>
	2	Protected against penetration of foreign solids 12 mm or larger	<ul style="list-style-type: none"> <li>• Touching or wishing with finger or analog objects whose length does not exceed 80 mm, internal parts under voltage or moving is prevented;</li> <li>• Penetration of foreign solid bodies with a diameter of 12 mm or more is prevented</li> </ul>
	3	Protected against penetration of foreign solid bodies of 2.5 mm or larger	<ul style="list-style-type: none"> <li>• Touching with tools, wires, etc. with a diameter or thickness of more than 2.5 mm, of the internal parts under voltage or in motion is prevented;</li> <li>• Penetration of foreign solid bodies with a diameter equal to or greater than 2.5 mm is prevented</li> </ul>
	4	Protected against penetration of solid bodies foreign than 1 mm or larger	<ul style="list-style-type: none"> <li>• Tapping with wires or bands over 1 mm thick, internal parts under voltage or moving is prevented;</li> <li>• Penetration of foreign solid bodies with a diameter equal to or greater than 1 mm is prevented</li> </ul>
	5	Protected partially against dust penetration	<ul style="list-style-type: none"> <li>• Touching in any way the internal parts under voltage or in motion is prevented;</li> <li>• The penetration of the dust is not completely obstructed, it can penetrate only to the extent that it does not impede the proper functioning of the electrotechnical product</li> </ul>
	6	Protected completely against dust penetration	<ul style="list-style-type: none"> <li>• Touching in any way the internal parts under voltage or in motion is prevented;</li> <li>• Dust penetration is completely obstructed</li> </ul>



Table 2. The significance of second characteristic figure

		NAME	EXPLANATIONS
THE SECOND CHARACTERISTIC	0	Unprotected	<ul style="list-style-type: none"> <li>Water penetration is not obstructed</li> </ul>
	1	Protected against vertical drops of water	<ul style="list-style-type: none"> <li>Water droplets falling vertically should have no harmful effects</li> </ul>
	2	Protected against drops of water falling below an angle of max. 15 ° to the vertical	<ul style="list-style-type: none"> <li>Drops of water falling below an angle of max. 15 ° to the vertical should not have harmful effects, ie drops of rain falling vertically do not damage the product inclined at an angle of max. 15 ° to the vertical</li> </ul>
	3	Protected against water falling as rain	<ul style="list-style-type: none"> <li>Water falling as rain, at an angle of max. 60 ° to the vertical must not have harmful effects</li> </ul>
	4	Protected against splashing with water	<ul style="list-style-type: none"> <li>Water sent from all directions on the housing must be free of harmful effects</li> </ul>
	5	Protected against water jets	<ul style="list-style-type: none"> <li>Water sent with a hose in all directions on the housing must be free of harmful effects</li> </ul>
	6	Protected against shipboard conditions	<ul style="list-style-type: none"> <li>Water from strong waves or jets must not penetrate the carcass in harmful quantities</li> </ul>
	7	Protected against the effects of immersion in water	<ul style="list-style-type: none"> <li>The penetration of harmful water into the enclosure completely immersed in water at a given pressure and time must not be possible (checked according to Table 4, figure 7)</li> </ul>
	8	Protected against prolonged immersion in water	<ul style="list-style-type: none"> <li>The product resists prolonged immersion in water under conditions specified by the manufacturer</li> </ul>
	9	Protected against high pressure and high water jets	<ul style="list-style-type: none"> <li>High pressure and high-temperature water from any direction on the housing must be free of harmful effects</li> </ul>

Enclosures of electrical or non-electrical equipment, whether used in normal environments or potentially explosive atmospheres, must provide a certain degree of IP protection.

In accordance with general standards that set out the basic methods and requirements for the design, construction, testing and marking of electrical and non-electrical equipment for use in potentially explosive atmospheres with gas, vapor, fog and combustible dust: SR EN 60079-0 and SR EN ISO 80079-36 it is necessary for the equipment to be provided with a housing with a specific IP protection degree for a certain type of protection. The specific test procedures are in accordance with the requirements of SR EN 60529-1995 / A1-2003 and SR EN 60529-1995 / A2-2015, and for rotary electric machines according to SR EN 60034-5.

If a characteristic number is not required, it should be replaced by the letter "X" (or "XX" if both digits are omitted), eg: IP6X; IPX7; IPX6 / IPX8).



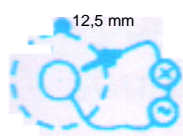








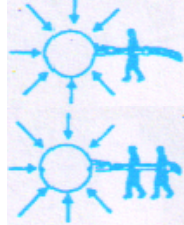

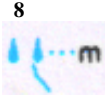
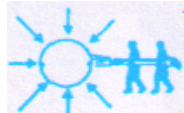
In practice, the following degrees of protection can be achieved, shown in Table 3.

Table 3. Degrees of protection

CODE	The first characteristic figure (solid bodies)	The second characteristic figure (water)									
		0	1	2	3	4	5	6	7	8	9
IP	0	IP00	-	-	-	-	-	-	-	-	-
	1	IP10	IP11	IP12	-	-	-	-	-	-	-
	2	IP20	IP21	IP22	IP23	-	-	-	-	-	-
	3	IP30	IP31	IP32	IP33	IP34	-	-	-	-	-
	4	IP40	IP41	IP42	IP43	IP44	-	-	-	-	-
	5	IP50	-	-	-	IP54	IP55	-	-	-	-
	6	IP60	-	-	-	-	IP65	IP66	IP67	IP68	IP69

The synthesis of the tests for determining the IP code digits is shown in Table 4 (SR EN 60529:1995/A2:2015 + SR EN 60529:1995/AC:2017).

Table 4 - The synthesis of the tests for determining the IP code digits

IP	Test	Description	IP	Test	Description
0		Unprotected	0		unprotected
1	50 mm 	protected against foreign solids with a diameter of 50 mm and above (protected from hand-held access to dangerous parts)	1		protected against drops of water falling vertically
2	12,5 mm 	protected against foreign solids with a diameter of 12 mm or more (protected against finger contact at dangerous parts)	2		protected against vertical droplets of water that can be rotated at 15 °
3	2,5 mm 	protected against solid foreign bodies with a diameter of 2.5 mm and higher (fine tools, wires)	3		protected against spraying water at an angle of up to 60 ° to the vertical
4	1 mm 	protected against solid foreign bodies with a diameter of 1 mm and higher (fine tools, wires)	4		protected against sprayed water on all sides
5		protected against dust (against hazardous deposits)	5		protected against jets of water from all sides
6		Dust-tight	6		heavy water jet, equivalent to sea waves during storm
			7		protected against immersion in water
			8		protected during permanent immersion in water (1000 mm)
			9		protected against strong water jets (high pressure and high temperature)

### 3. Improvement methods and technical tests for technical equipment

In the framework of the PN - ELTOX project, in the ENExEMEIP Laboratory, the principle diagrams were developed and the tender dossiers for the purchase of two test stands were elaborated:

- A dust chamber designed for large-scale equipment to determine partial or total dust protection (IP 5X and IP 6X);
- An automated stand for water spray testing (IP X3 and IP X4).

According to the basic principles presented in Fig. 1 in which the dust circulation pump can be replaced by other means to keep the suspension of talcum powder in a closed test chamber. The talc powder used must be able to pass through a square mesh fabric at which the nominal yarn diameter is 50 µm and the free space between threads of 75 µm. The talc powder used is 2 kg per cubic meter of the test chamber. The talc should not be used in more than 20 attempts.

Depending on the category established by the manufacturer, the dust-proofing test inside the equipment is carried out using the vacuum pump (for category 1 carcasses) and without the vacuum pump (for category 2 carcasses).

According to SR EN 60529-1995 / A1-2003, the electrical equipment casings are divided into two categories:

- Category 1: enclosures where the normal operating cycle of the equipment causes reductions in internal pressure relative to ambient air due, for example, to the effects of thermal cycles.
- Category 2: housings in which there is no pressure difference with respect to ambient air.

In general, machinery intended for use in potentially explosive atmospheres of fuel-dust atmospheres must have a standard IP 5X or IP 6X protection rating and enclosures when testing for the first characteristic figure: -5- protection partial dustproofing, ie total protection against dust penetration, are considered to be of category 1, which in the normal operating cycle are heated and therefore the test is carried out in the dust chamber using the vacuum pump.

The pump connection must be made through a hole specially designed for this test. Without a different specification from the specific product standard, this hole must be in the vicinity of vulnerable parts. If there are other holes (eg other head inlets or outlet holes), they should be treated as normal.

The purpose of the test is to pass through the housing, with a depression, a volume of air equal to 80 times the volume of the test case without exceeding a 60-hour extraction rate of the carcass volume. Under no circumstances should the depression be greater than 2 kPa (20 mbar) in the manometer shown in Figure 2. If the extraction rate is 40 to 60 volumes per hour, the test takes 2 hours.

For testing the characteristic digit IP 5X or IP 6X for large-dimension equipment, use the dust chamber shown in Fig. 1.

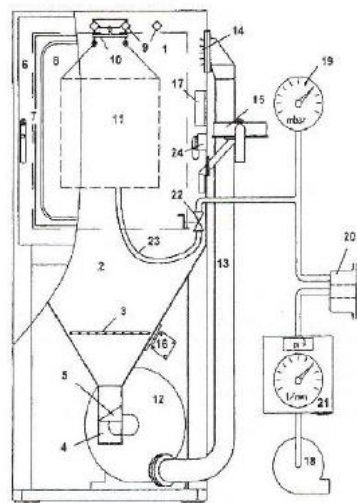


Fig. 1. Dust test Chamber – principal scheme

Enclosures with the degree of protection IP 5X “Dust protected” do not have to prevent ingresses of dust totally. However, dust should not penetrate in an amount sufficient to interfere with the satisfactory operation of the equipment enclosed or to impair safety. In the case of enclosures with degree of protection IP6X “Dust tight” it is necessary to prove that no dust can penetrate into the inside of the enclosure. The test are carried out by means of a dust chamber with a sealed test cabinet, in which talcum powder is kept in suspension by means of an air stream. The talcum powder must be prepared in such a manner that it will pass through a sieve with a mesh size of 0,075 mm. The quantity of talcum given in the regulation is 2 kg per cubic of test cabinet volume.

Attempts to protect against water penetration, indicated by the second characteristic figure, are performed with fresh water. During the tests for IP X1 to IP X6, the water temperature must not differ by more than 5 K from that of the product under test. In the case of tests for determining the IP X9, the equipment protected against strong water jets is subjected to high pressure and high temperature (upon agreement between the beneficiary and the manufacturer).

During the test, moisture inside the housing may partially condense. The condensing water that is deposited should not be considered as the penetration of the outside water.

To test the characteristic figure IP X3 or IP X4 in the case of small size equipment, an automated oscillating tube stand is used, as shown in Fig. 2.

The stand has been designed to provide: an adjustable height of 500 to 1250 mm, the possibility of installing an oscillating spring with a radius between 200 ... 1800 mm; the adjustable speed of the oscillating spring (adjustable); possibility of limiting oscillation angle (oscillations of almost 3600, 1800 on both sides of the vertical); adjustable test duration between 1 and 60 min; adjustable pressure, flow adjustment 30 ... 300 l / h; rotary sample placement with automatic oscillating motion and oscillating speed adjustment.

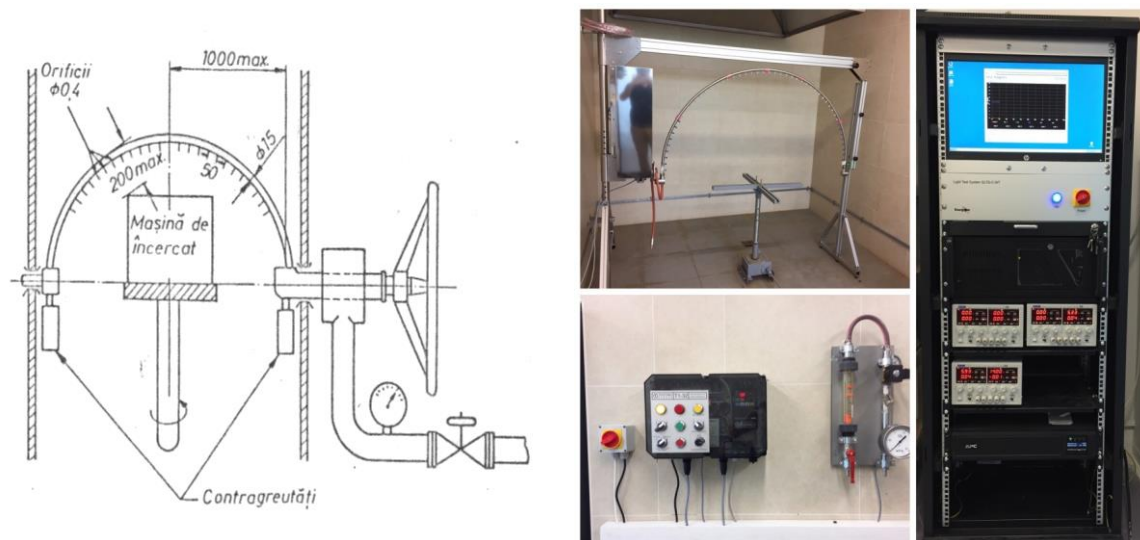


Fig. 2. Apparatus for checking the protection against falling rainwater and water projections; The second characteristic number 3 and 4 (oscillating tube)

## 5. Conclusions

Dust and water penetration tests inside electrical and non-electrical equipment, ie the determination of the first characteristic number IP 5X and IP 6X, or the determination of the second characteristic digit IP X3 and IP X4 of the normal protection degree with the stands The above test is particularly important for assessing the compliance of the equipment with the requirements of the harmonized European standards and the explosion protection requirements of the ATEX Directive, taken over in the Romanian legislation by GD 245/2016.

In order to perform these tests, the ENExEMEIP laboratory at INCD-INSEMEX Petroșani designed the technological schemes and elaborated the specifications for the purchase of a large-scale powder testing chamber and an automated water test stand in the form of rain. The stands meet the requirements of SR EN 17025, these tests may be included in the accredited testing field within the GLI laboratory.

By providing these stands, the test conditions are met to meet the demand of various manufacturers / manufacturers, importers, distributors or users for verification / certification of electrical and non-electrical equipment intended for use in potentially explosive atmospheres.

## Acknowledgements

This paper was developed within the Nucleu - Programme, carried out with the support of MCI, project no. PN 18 17 02 01.

## References

- Vătavu N., *PNCDI C49 theme A13/99 - Research on safety requirements for electrical equipment intended for use in the presence of combustible dusts in order to comply with European standards*;
- Părăian M., Găman G.A., Lupu C., Ghicioi E., Burian S., Vătavu N., Ionescu J., Jurca A., Friedmann M., Păun F., Magyari M., Lupu L., Moldovan L., Muntean Berzan F., Csaszar T., Vlasin N., Darie M., *Guidelines for evaluation of systems and personal protective equipment on the risk of explosions in environments with potentially explosive atmospheres (in Romanian), INSEMEX Publisher, Petrosani, Romania, (2014)*;
- SR EN 60529:1995 + SR EN 60529:1995/A1:2003 + SR EN 60529:1995/A2:2015 + SR EN 60529:1995/AC:2017 - *Protection classes provided by enclosures (IP code)*.
- SR EN 60034-5: 2003 + SR EN 60034-5: 2003/A1:2007 - *Rotary electrical machines. Part 5. Normal protection classes ensured by the complete design of rotating electric machines (IP code). Classification, (2007)*.
- SR EN 60079-14: 2014 + SR EN 60079-14: 2014/AC:2016 - *Explosive atmospheres. Part 14: Design, selection and construction of electrical installations, (2014)*.

## Researches on the macroelements content from Jiu Valley coal ash

Alexandru Simion<sup>a\*</sup>, Angela-Nicoleta Călămar<sup>a</sup>, Lorand Toth<sup>a</sup>,

Marius Kovacs<sup>a</sup>, Sorin Simion<sup>a</sup>

<sup>a</sup>National Institute for Research and Development in Mine Safety and Protection to Explosion – INSEMEX Petroșani,  
32-34 G-ral Vasile Milea Street, Postcode: 332047, Petroșani, Hunedoara County, Romania

---

### Abstract

Worldwide, there is an increasingly acute crisis of raw materials coming from conventional resources. A way to confute this crisis is the exploitation of waste from different industries, their processing becoming competitive in the conditions of increasing costs of extracting some useful minerals.

This paper aims to establish the chemical composition (macro elements) of raw coal ashes from the Jiu Valley from several mining units and to establish the chemical composition of special products from the Jiu Valley Preparation Plant in order to make an optimal decision in case of possible capitalization.

From research carried out so far on raw coal ashes and special products in Jiu Valley, it has been found that there is a concentration above the average of European Union countries of metal oxides present in the coal ashes. Large amounts of ashes, exploitation efficiency and waste recycling tendency considerably reduce the technical and economic difficulties of extraction from non-bauxitic raw materials. Thus, the existence and composition of these macro elements was studied using the process of dissolving alumina in HNO<sub>3</sub> in a quantity less than the stoichiometric value, when Al(NO<sub>3</sub>)<sub>3</sub> • 9H<sub>2</sub>O is formed, because the iron remains insoluble in the solution afterwards being extracted from moist and dried concentrates in soft or strong fields.

Keywords: ash; coal; environment, macroelements;

---

### 1. Introduction

In the last three decades, the dynamics of global coal production has regressed under the influence and competition of other sources of primary energy, respectively oil and natural gas. Very economic advantageous exploitation conditions of hydrocarbon reservoirs, and in particular those in economically weak countries, has weighted the world balance of primary energy carriers against coal.

Typically, raw coal (as extracted from deposit) does not fully correspond to quality of various uses or technological processes. In order to bring it into the state demanded by consumers and to be used in the most economical way, coal is subjected to physical and physical-chemical processing operations, called preparation operations.

Coal preparation comprises a complex of mechanical operations (grading, grinding, concentrating, draining, etc.) to which raw coal is subjected in order to improve its quality and to adapt it to different processes where it is to be used or recovered. As a result of coal preparation process, a special product is produced in which the structure and chemical composition of coal is not changed.

Ash represents the inorganic mass of coal formed by oxidation at 850°C. A series of elements known as minor elements or trace elements, in quantities between 1 ppm and 1% (Au, Ag, Pt, Co, Ga, In, Mo, Ni, Sn, V, Cu, Pb, Zn, Cd, etc.) and elements known as major elements or macroelements in quantities of more than 1% by weight of ash (SiO<sub>2</sub>, Al<sub>2</sub>O<sub>3</sub>, Fe<sub>2</sub>O<sub>3</sub>, CaO, MgO, SO<sub>3</sub>, Na<sub>2</sub>O, K<sub>2</sub>O) are present in coal ash (Simion, 2014).

Coal ashes from thermoelectric plants, because of their content in various metallic oxides, are considered as new sources of raw materials. From research carried out on ash recovery, the question was put to use ashes from energetic complexes (CTE) by first extracting metal oxides (Fe<sub>2</sub>O<sub>3</sub>, Al<sub>2</sub>O<sub>3</sub>) usable in metallurgical industry followed by the use of by-products resulted for obtaining products (Ghiță et al., 1973), (Simion, 2014).

---

\* Corresponding author. Tel.: +40 254 541 621; Fax: +40 254 546277.  
E-mail address: alexandru.simion@insemex.ro;

## 2. Content of macroelements in coal ashes

Chemical composition of ashes is particularly complex, the content and oxidic nature varying widely, depending on the genesis of coal (Petrescu et al., 1987). From mineralogical observations performed on coal-based minerals, specialists noted that they are made up of 95% loamy minerals and the rest of 5% of associated minerals are: pyrite, marcasite, dolomite, siderite, calcite, sodium and potassium halides, quartz, feldspar, magnetite, topaz, tourmaline, hematite, etc. (Petrescu et al., 1987).

In some countries, such as Poland and France, there are industrial installations for extracting metallic oxides from coal ash. In Romania, because there are no such installations, there is a need to compare ash composition in some European countries (Table 1) with ash composition in our country to check tailings quality.

Table 1. Coal ash composition in some European countries and U.S.A.

Country	Composition %						
	SiO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub>	Fe <sub>2</sub> O <sub>3</sub>	CaO	MgO	SO <sub>3</sub>	Na <sub>2</sub> O+K <sub>2</sub> O
Great Britain (L)	41.4-50.7	28.6-29.9	6.4-13.3	1.7-3.7	1.4-2.9	0.6-1.8	2.0-6.1
Austria (L)	45.0-53.0	19.0-24.0	6.0-9.0	10.0-13.0	2.0-3.0	-	-
France (H)	47.0-53.0	28.0-35.0	3.6-11.5	13.4	1.4-2.5	0.1-0.9	0.9-7.3
Germany (L)	28.0-68.0	3.2-11.4	2.3-6.5	16.3-24.9	0.5-2.6	5.8-16.3	-
Greece (L)	33.0	15.5	6.0	33.0	2.0	6.0	3.0
Poland (H)	43.0-57.0	18.0-28.0	7.5-16.0	4.0-10.0	1.0-5.5	0.5-3.3	1.0-3.0
Spain (L)	36.4-51.4	11.6-34.8	7.6-27.9	0.9-11.3	0.9-2.9	0.3-3.4	0.1-3.3
U.S.A. (L)	34.0-38.0	17.3-31.0	6.0-26.0	1.0-10.0	0.5-2.0	0.2-4.0	1.5-2.0
Romania							
Pit coal (H)	38.0-51.0	23.0-32.0	7.0-18.0	1.0-6.0	0.9-3.0	0.9-3.0	1.0-3.0
Lignite (L)	35.0-54.0	11.0-25.0	7.0-23.0	3.0-28.0	1.0-4.0	0.2-15.0	1.0-4.0

Note: Pit coal – (H), Lignite – (L)

Table 1 shows that in countries such as United Kingdom, Austria, France, Germany, Poland, Spain and Romania, the coal sterile is of aluminous-silicone type and only in Greece and USA the coal sterile is of calcic type.

In comparison, table 2 shows our research on the chemical composition of coal ash oxides from Jiu Valley, on mining operations, composition measured in the chemistry laboratory (Simion, 2014).

Table 2. chemical composition of coal ash oxides from Jiu Valley

No.	Mine	SiO <sub>2</sub>	Fe <sub>2</sub> O <sub>3</sub>	Al <sub>2</sub> O <sub>3</sub>	TiO <sub>2</sub>	CaO	MgO	SO <sub>3</sub>	Na <sub>2</sub> O	K <sub>2</sub> O
		(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
1	Lone	49.43	10.25	23.23	0.57	7.48	2.29	2.59	2.42	0.87
a										
2	Petrit	52.29	10.51	18.96	0.78	6.60	2.69	2.35	2.97	0.73
a										
3	Livez	53.26	8.31	25.69	1.04	4.44	2.20	2.30	2.10	0.53
eni										
4	Vulca	53.69	9.78	20.5	0.71	7.48	1.35	2.65	2.78	0.75
n										
5	Paroș	51.69	7.75	19.29	0.92	7.71	1.35	3.39	2.98	0.84
eni										
6	Lupe	53.91	8.31	25.69	0.83	4.44	2.02	2.24	1.67	0.4
ni										
7	Bărbă	49.81	8.05	23.70	0.83	6.78	1.34	2.34	2.76	0.93
teni										
8	Urica	52.78	12.84	17.20	0.82	5.14	1.85	2.77	2.93	0.87
ni										

The diagram of the macroelements distribution in these ashes is shown in Fig. 1.



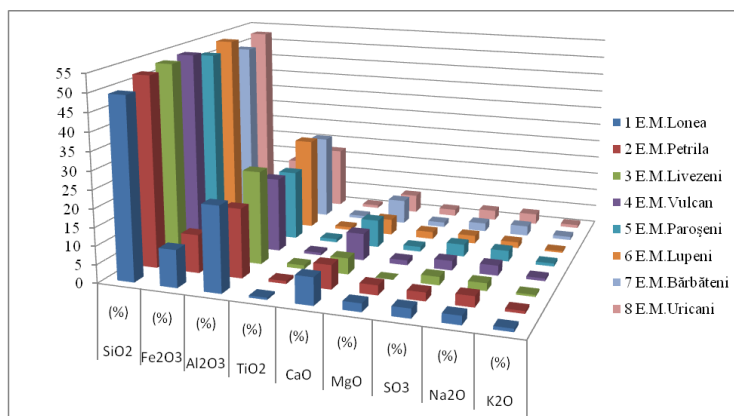


Fig. 1. Diagram of the macroelements distribution

The analysis of macroelements content in Jiu Valley coal ashes, shows that the SiO<sub>2</sub> content is high, classifying the coal ash into a high abrasive class, complicating the extraction process and increasing the production cost of metals obtained, but the content of useful metals and other elements that can be extracted tilts the balance in favour of ashes exploitation, to capitalize the waste resulting from oxidation.

Depending on the chemical composition of ashes, the recovery manner and technology are chosen and the chemical composition of coals actuates its behaviour in the combustion process in the furnaces of steam boilers. Thus, a high content of alkanes acts as a fusing agent, leading to slagging of ashes (Ionescu and Moldovan, 2005). Ashes containing iron oxides are more fusible than those containing aluminium oxide and silicon dioxide. A high content of silicon dioxide may indicate the presence of a significant amount of free quartz in the tailings, which generates a high abrasiveness of ash (Ghiță et al., 1973).

Higher content of sulphur trioxide in the ash composition can lead to corrosion of the boiler, accompanied by pollution of the atmosphere with sulphur oxides, harmful to flora and fauna. Knowledge of the composition of inorganic mass of coals is particularly important, not only in the case of its use for energy, but also in the case of metallurgical coal, which must have an as low as possible ash content, as it runs into coke (Moldovan et al, 2003; Moldovan and Ionescu, 2006).

### 3. Content of macroelements in special products ashes

In order to establish the chemical composition of ashes, coal was extracted from 4 mining coal mines, coal subjected to the preparation process at Coroiești Coal Preparation Plant. The methods of analysis used are in line with current standards for determining the chemical composition of ash, applicable both in industrial processes and in laboratory (STAS 10274/4-90; STAS 10274/5-75; STAS 10274/5-7).

The ash used in our case is the result of burning special coals in laboratory. The chemical analyses were carried out on three parallel samples, resulting in a final arithmetic mean of results that matched the corresponding values for maximum admissible differences for each determination method (STAS 10274/4-90; STAS 10274/5-75; STAS 10274/6-88).

The chemical composition of the special coal ash resulted from Coroiești Preparation Plant is shown in Table 3.

Table 3. Chemical composition of the special coal ash resulted from Coroiești Preparation Plant

N o.	Preparation plant	Oxides (%)								
		SiO <sub>2</sub>	Fe <sub>2</sub> O <sub>3</sub>	Al <sub>2</sub> O <sub>3</sub>	TiO <sub>2</sub>	CaO	MgO	SO <sub>3</sub>	Na <sub>2</sub> O	K <sub>2</sub> O
1	Petrila	39,89	15,60	25,81	1,33	6,72	1,00	5,93	2,01	0,72
2	Livezeni	39,06	13,51	27,56	1,57	3,50	2,02	4,19	6,52	0,61
3	Vulcan	38,99	18,45	24,16	1,25	7,71	1,26	4,63	2,06	0,73
4	Lupeni	35,67	13,61	29,25	0,92	6,60	2,18	4,66	5,46	0,85

The diagram of macroelements distribution in the special product ash from Jiu Valley Preparation Plants is shown in Figure 2.



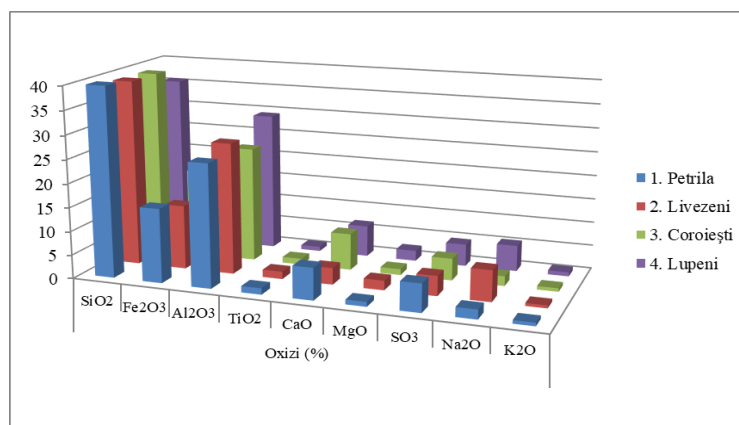


Fig. 2. Macroelements distribution in special product's ashes

Compared to the previous situation, for ash obtained by oxidation of special coals resulting from the preparation process, the metal oxide content has improved, for alumina by up to 52% and for iron oxides by up to 62%.

The distribution of macroelements in the special product ash from Coroiesti Preparation Plant (fig. 2) shows that the useful elements replace the silicon dioxide content, which reduces cost of maintenance for combustion boilers and capitalizes the recovery cost of metallic oxides from coal ashes.

Coal preparation doesn't have only positive effects, as sulphur trioxide (SO<sub>3</sub>) content of the coal mass doubles, leading to a much higher level of sulphur oxides emitted into the atmosphere, requiring a gas desulphurisation plant or a modernization of the existing one.

Sulphur trioxide also creates problems in ash dumps or tailings ponds because it reacts very easily with meteoric water forming acidic hydrogen ions and mineral acidity on its path that even in case of pollution, natural receptors become unusable for domestic consumption, riverbeds are covered with precipitate that contaminates the water source and inhibits or eliminates a variety of aquatic organisms, causing severe imbalances in the food chain (Lazar and Dumitrescu, 2006). By extracting these elements from ashes, these impacts can be minimized and we will have an excess of raw material, a much less polluted area with natural landscapes, with no opportunistic species capable of inhibiting the ecosystem restoration capacity (Lazar and Dumitrescu, 2006).

After the extracting these metals, coal ash could be used as: filling material in various road works, raw material in cement production, raw material in clinker blocks production, improvement products in agriculture, anti-skid, fire and frost high resistance material etc.

Onward, we suggest a few technologies for the extraction of iron oxides and alumina from coal ashes.

#### 4. Extraction of iron oxides and alumina from coal ashes

The natural reserves of non-aluminous materials of alumina-silicate type (kaolin, clays, etc.), as well as ashes from C.T.E. regardless of the type of coal, suitable for alumina production, can be considered as inexhaustible. This view is all the more rational as global coal-based energy will record an average growth rate of 2.3% per year by 2020, less than the projected 2.6% increase, but also a real increase of 3.4% per year between 2007 and 2012, according to International Energy Agency (IEA) estimates (International Energy Agency, 2018). Experts approximate that Romania has coal, especially coal and lignite, for another 250 years (International Energy Agency, 2018).

Literature in the field (Matjie et al., 2005), recommends the use of two different technologies for the production of alumina from non-aluminous raw materials, depending on the removal of iron from nitrate solutions, namely:

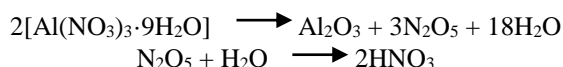
- dissolving in HNO<sub>3</sub> below the stoichiometric value, when Al(NO<sub>3</sub>)<sub>3</sub> · 9H<sub>2</sub>O is formed in contact with which the iron remains insoluble (Matjie et al., 2005);
- dissolving in HNO<sub>3</sub> over the stoichiometric value, when Al(NO<sub>3</sub>)<sub>3</sub> · 9H<sub>2</sub>O is formed and the iron passes into a solution where it is subsequently removed (Matjie et al., 2005);

In order to obtain Al<sub>2</sub>O<sub>3</sub> from the Jiu Valley coal ash by treatment with HNO<sub>3</sub>, dissolution in HNO<sub>3</sub> below the stoichiometric value was used, Al(NO<sub>3</sub>)<sub>3</sub> · 9H<sub>2</sub>O was formed, which in contact with the iron remained insoluble (fig.3) (Matjie et al., 2005) and for laboratory alumina production ash from Paroşeni thermal plant was used.

Optimal conditions for the leaching phase, reflected by an efficient output of alumina extraction and iron separation are:

- HNO<sub>3</sub> concentration = 40%;
- HNO<sub>3</sub>/Al<sub>2</sub>O<sub>3</sub> ratio = 0,9;
- Leaching temperature: 220°C
- Leaching time: 2 hours

After filtration of the pulp to separate soluble aluminates from insoluble iron compounds  $\text{Fe}_2\text{O}_3$ ,  $\text{Fe}(\text{OH})_3$ , the resulting solution was evaporated and crystallized. After leaching and sedimentation, water was liberated at  $120^\circ\text{C}$ , while increasing the concentration of  $\text{Al}_2\text{O}_3$  in solution. It was then treated with a 5%  $\text{HNO}_3$  solution at  $100^\circ\text{C}$  and exposed to crystallization. The aluminium oxide was crystallized as  $\text{Al}(\text{NO}_3)_3 \cdot 9\text{H}_2\text{O}$  and the next step consisted of breakdown of this compound into  $\text{Al}_2\text{O}_3$  and  $\text{HNO}_3$  according to the reactions:



In order to make the process more profitable, the issue of nitrate solution deferrization has been raised. The  $\text{Fe}_2\text{O}_3$  content of the solution after leaching was 0.3g/l (0.4%  $\text{Fe}_2\text{O}_3$ ) and 0.3%  $\text{Al}(\text{NO}_3)_3 \cdot 9\text{H}_2\text{O}$ . The solution obtained from the leaching process was improved by red-sludge treatment from the extraction of alumina from bauxite, resulting in an enriched preconcentrate.

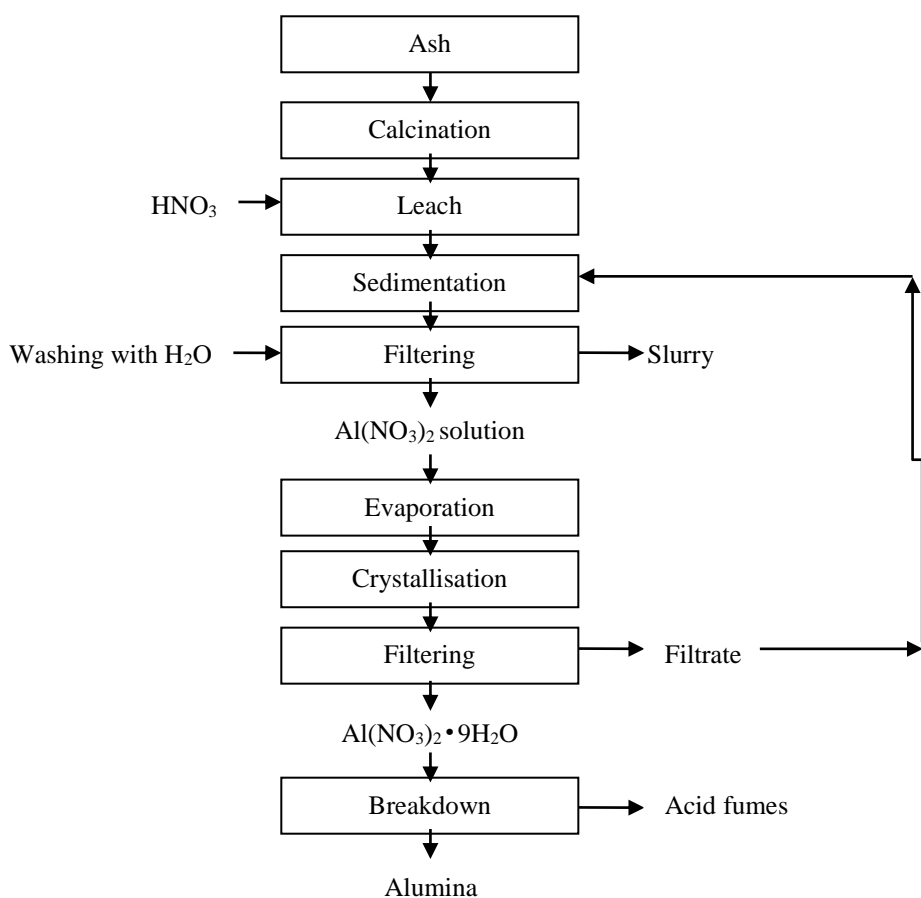


Fig. 3. Flow diagram of alumina production process by treatment with  $\text{HNO}_3$  (Matjie et al., 2005)

Concentrations of metallic oxides present in the preconcentrate do not fall within the limit of industrial phase exploitation, and in order to move to the industrial phase two more problems needed to be solved:

- deferrization of aluminium oxide to the limit required by the norms for obtaining aluminium for electrolysis;
- increasing the recovery rate of nitrogen oxides, respectively nitric acid.

Obtaining iron oxide concentrates represents a major concern at the present stage for the complex and integral use of ashes from C.T.E. In order to obtain iron oxide concentrates from the ashes, especially methods based on the principle of magnetic separation were examined (Friedeberg, 1995). The chemical composition of ashes has shown the presence of magnetised oxides (magnetite, hematite) and compounds of manganese, calcium, magnesium, which improve the quality of iron concentrates (Friedeberg, 1995). For iron and steel metallurgy, the absence of copper, silver, arsenic, sulphur, etc. from the ashes represents an advantage because these elements belong to non-ferrous metallurgy and make it difficult to extract iron oxides (Lazar and Dumitrescu, 2006).

The separation of iron oxides from ashes has a double importance and necessity:

- attaining a new source of ferrous metal concentrates usable in steel industry;
- deferrization of ashes from C.T.E. for their use in alumina production.

Magnetite type Iron minerals are of interest for the purposes pursued. Magnetite and hematite have been identified in both the free grains as well as punctiform impregnated in the quartz and silicate masses. The most commonly used methods for obtaining concentrates refer to wet separation in weak magnetic fields and dry separation in strong magnetic fields. Concentration through flotation has an increased output for iron ores or ashes of weak magnetic components (Friedeberg, 1995; Negoiu, 1970).

The technology, consisting of weak field magnetic preconcentration, followed by grinding the preconcentrate to a fineness of less than 0.2 mm followed by a new weak field magnetic separation was verified on a pilot scale.

The preconcentrate obtained by applying a magnetic field of 11900 A / m intensity has the composition of shown in Table 4.

Table 4 Composition of preconcentrate obtained by applying a magnetic field of 11900 A / m intensity

Fe (%)	SiO <sub>2</sub> (%)	Al <sub>2</sub> O <sub>3</sub> (%)	CaO (%)	Mn (%)
35	25.2	10.7	2.0	0.31

## 5. Conclusions

Centralized data shows significant variations in the chemical composition of ash according its origin. As with coal ashes in other countries, there is a higher content of SiO<sub>2</sub>, Al<sub>2</sub>O<sub>3</sub> and Fe<sub>2</sub>O<sub>3</sub> and lower in other elements (TiO<sub>2</sub>, CaO, MgO, SO<sub>3</sub>, Na<sub>2</sub>O, K<sub>2</sub>O). Ashes also have a high SO<sub>3</sub> content, which indicates that a reduction in the sulphur content of their composition is required. With the extraction of iron and aluminium oxides, a magnetic field preconcentration has been obtained which reveals that the reuse of a large amount of ash can alleviate or solve environmental problems. Moreover, besides solving environmental problems, the use of ash is a way to save natural resources and energy.

## 6. Acknowledgements

This paper was carried out through the EXTOTOX Program, implemented with the support of Romanian National Authority for Scientific Research, project no. 18 17 01 01, „Developing the institutional capacity to carry out technical expertise of events such explosion / fire”.

## References

- Friedeberg, H., Separation and determination of Microgram Quantities of Silver, Mercury, and Copper with Dithizone, *Anal. Chem.*, Vol.27, No.2, pp. 305-306, (1995).
- Ghiță, I., Faur, V., Crișan, D., Possibilities of capitalizing the iron from the ashes of C.T.E Mintia, *Conference on Ash Capitalizing from C.T.E. Deva*, (1973).
- Ionescu, C., Moldovan, C., *Coal chemistry*, Bren Publishing House, Bucharest, (2005).
- International Energy Agency, *Coal Information* (2018).
- Lazar, M., Dumitrescu, I., *Antropic impact on the environment*, Universitas Publishing House, Petroșani, (2006).
- Matjie, R.H., Bunt, J.R., van Heerden, J.H.P., Extraction of alumina from coal fly ash generated from a selected low rank bituminous South African coal, *Minerals Engineering*, Vol. 18, No. 3, pp. 299-310, (2005).
- Moldovan, C., Ionescu, C., Coal extraction in solvents, *10<sup>th</sup> Conference on Environment and Mineral Processing*, Ostrava, Czech Republic, (2006).
- Moldovan, C., Ionescu, C., Sbârnă, S., Sbârnă S., Reducing ash content of coal by chemical processes, *ROPET International Symposium*, pp. 165-168, Petroșani, (2003).
- Negoiu, D., *Treatise on inorganic chemistry*, vol. I, Tehnical Publishing House, Bucharest, (1970).
- Petrescu, I., Bițoiu, C., Nicorici, M., Mărgărit, G., Nicorici, E., Pătruțoiu, I., Todros, C., Popescu, D., Ionescu, M., Dușa, A., Munteanu, A., Buda, A., *Geology of coal deposits*, Editura Tehnică Publishing House, Bucharest, (1987).
- Simion, A.F., *Possibilities for the extraction of rare metals from the coal ash of Jiu Valley*, License paper, Petroșani, (2014).
- STAS 10274/4-90 Ash analysis. Measurement of iron.
- STAS 10274/5-75 Ash analysis. Measurement of aluminum.
- STAS 10274/6-88 Ash analysis. Measurement of titanium.

## Opportunity of using drones equipped with sensors for measurement of combustion gases

Marius Kovacs<sup>a</sup>\*, Angelica-Nicoleta Călămar<sup>a</sup>, Lorand Toth<sup>a</sup>,

Sorin Simion<sup>a</sup>, Alexandru Simion<sup>a</sup>, Kovacs Izabella<sup>a</sup>

<sup>a</sup>National Institute for Research and Development in Mine Safety and Protection to Explosion – INSEMEX Petroșani,  
32-34 G-ral Vasile Milea Street, Postcode: 332047, Petroșani, Hunedoara County, Romania

---

### Abstract

Through smokestacks, combustion plants discharge flue gases into the atmosphere, gases containing significant amounts of polluting substances such as: gaseous noxae (sulphur oxides - SO<sub>x</sub>, nitric oxides - NO<sub>x</sub>, carbon monoxide and dioxide - CO and CO<sub>2</sub>); as well as flue dust (suspended particulate matter - aerosols, precipitate dusts), unburned and soot. At present, methods used to measure ambient air concentrations are continuous methods that are fully automatic (monitoring stations) and discontinuous instrumental methods, using numerical display devices equipped with sampling probes.

There are situations in which the smokestack does not have inspection holes for taking samples or there is no platform located at the appropriate height (recommended by normative acts) or certain situations where the smokestack height is 30-50 m making it impossible to sample burned gases.

Lately, drones have become more and more intelligent, and given the current complexity and performance of hardware and software, we could say that this development will take place swiftly. The current paper explores the possibility of using drones equipped with gas sensors to measure industrial gas emissions from large combustion plants. In this case, account shall be taken of air currents generated by drones and temperature of discharged exhaust gases.

This method has a character of novelty because drones are not currently used in industry.

The results of the research will conclude if drones equipped with sensors will or will not be widely used in this field, given their advantages and disadvantages. Furthermore, this paper will be a starting point for future research regarding gas emissions measurements both by using drones and the standardized measurement method (sampling inside smokestacks). Also, the use of aerospace vehicles (drones) will be a real help for improving services, quick reaction in case of damages, for the safety and security of workers.

*Keywords:* emissions; combustion gases; drone..

---

### 1. Generalities

A drone is an UAV aircraft (Unmanned Aerial Vehicle), able to fly without being piloted by a person, which was originally used only for military purposes for the recognition of targets and bombing of strategic targets.

What differentiate drones from other unmanned aerial vehicles (UAVs) is, firstly, their much-reduced size and weight, then the fact that power supply is provided by a battery or other power source.

Except for military drones, areas of use for civilian drones (figure 1) are multiple, applications being even scientific. They have the following features and benefits:

- Positioning and movement are usually based on GPS system;
- Feature a powerful onboard computer and sensors, or other devices such as high-resolution and infrared video or photo cameras, range finders, radars, etc;
- Data transmission or communication with the checkpoint is done either by radio or via the internet and devices including PCs, tablets and smart phones can be used as control devices;
- Are able to independently come back to where they left;

---

\* Kovacs Marius. Tel.: +400254541621; fax:400254546277.

E-mail address: marius.kovacs@insemex.ro.

- Because power is supplied from a battery, they have a reduced period of operation - the drones autonomy expanding from tens of minutes to several hours;
- Are silent when in use and at high altitudes/ distances they become difficult to see with the naked eye;
- Are able to maintain stable at a fixed altitude or within a certain position;
- Are resistant to shocks and exposure to water or high temperatures.

#### ***Components of multirotor drones***

The construction of the drone begins with the skeleton or the drone frame. It is made of lightweight materials resistant to static and dynamic stresses such as duralumin or carbon fibre, and can also be made of expanded polypropylene or nylon fiber reinforced high-density plastic (Figure 1). Both trussed beams and tube-type elements are used depending on the size of drones and number of motors. The frame is made by joining the motor port arms with a central connecting piece in a rigid structure. In addition to supporting the engines and the landing gear, the frame must provide the possibility of fastening electronic flight control modules and camera or auxiliary devices. The landing gear is attached to the frame structure by means of shock absorbers and can be rigid or retractable.



Fig. 1. Multirotor drone

Each arm supports an electric motor that will operate a propeller. Brushless motors are used due to increased efficiency by reducing friction compared to brush and collector motors as well as due to very low power losses. For choosing the engines, the total weight of the drones and their accessories must be known.

Multirotor drones use propellers that rotate in opposing directions. The important parameters of the propellers are the length and the pitch. Larger length and higher pitch improve the ascent force.

Of all existing battery types, the lithium-polymer batteries are best suited for charging drones because of their physicochemical properties. They present a number of advantages over both Lithium (Li-ion, Li-Fe) and Nickel-based (NiMh, NiCd) batteries.

## **2. Aerodynamics of drones and the air currents they form**

Through their operation, drone's propellers move large amounts of air forming whirls. These air currents generated by drone rotors influence any gas sensor placed in their immediate vicinity (Patrick et al 2012).

Aerodynamic forces are modeled to consider the variation of push coefficients with different flight conditions, in order to calculate the aerodynamic effect of traction and traction upon propulsion rotation. This aerodynamic analysis is very useful to predict the dynamic behavior of the system in the presence of wind fields and gives us indications of the type of propeller and characteristics of the engine to be installed on the drones.

Figure 2 shows the classical configuration of a quadrotor. The four rotors are labeled from 1 to 4 and are fitted at the end of each transverse arm. A pair of rotors spins clockwise while the other pair rotates counterclockwise: this way it is possible to avoid the return deviation due to reactive torques and lateral movement without changing the pitch of the blade propeller. Fixed point simplifies rotor mechanics and reduces gyroscopic effects.

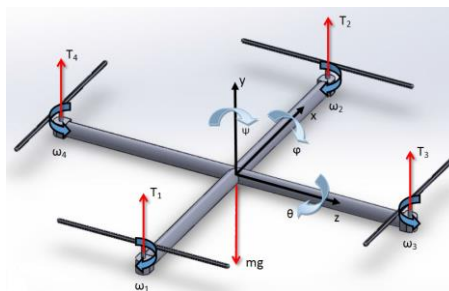


Fig. 2. Quadrotor force and axle system  $T1 \div T4$  - Traction force due to rotation,  $\omega1 \div \omega4$  - angular velocity vectors, x, y, z - drone displacement axes

According to figure no. 3 a and b, a series of whirls are formed around the drones which are difficult to evaluate.

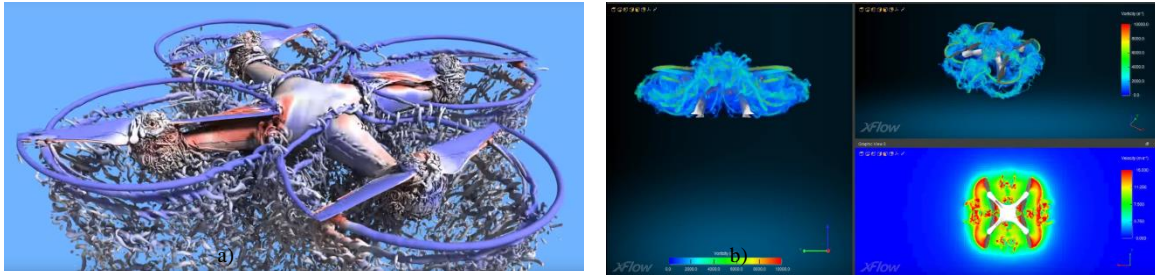


Fig. 3. Exploring drone aerodynamics with computers. a) 3D view, b) analysis using the X Flow program

The simplest theory to estimate the performance of a propeller is the impulse theory. This model uses an ideal fluid, respectively the air is incompressible, not viscous and irrotational, while the propeller is modeled as a disk with the same area described by the propeller rotation. This disc produces an evenly distributed pressure jump when flowing through it (Andres M P G, 2017). Figure 4 shows the model sketch.

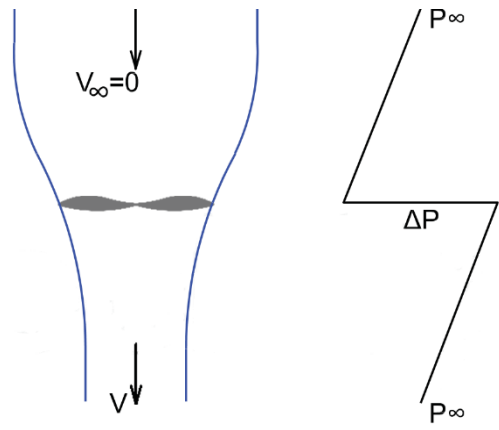


Fig. 4. Simplifying the disk for impulse theory

Applying the Bernoulli equation to fluid before the disk,

$$p_{\infty} = \frac{1}{2} \rho v_i^2 + p_i \quad (1)$$

where  $\rho$  is air density,  $v_i$  is the disk-induced velocity at the fluid,  $p_i$  is the pressure just before the disc, and  $p_{\infty}$  is the pressure of the uninterrupted liquid. Applying Bernoulli after the disc,

$$\frac{1}{2} \rho v_i^2 + p_i + \Delta p = p_{\infty} + \frac{1}{2} \rho v_{\infty}^2 \quad (2)$$

where  $v_i$  is infinite downstream speed, see Fig. 4. from equation 2 and 3.

$$\Delta p = \frac{1}{2} \rho v_{\infty}^2 \quad (3)$$

$$T = \Delta p \cdot A \quad (4)$$

where  $T$  is the push,  $\Delta p$  is the increase of the pressure caused by the propeller and  $A$  is the disk area according to equation 5:

$$T = \frac{1}{2} \rho A v_{\infty}^2 \quad (5)$$

International research highlighted the whirls created by a propeller spinning at 4500 rpm and the structure of currents indicates that the strongest vortex is created at the tip of the blade, as well as the fact that the peak vortex and the inner vortex descend below the rotor following a helical trajectory (fig. 5.).



Controlling a quadcopter is based on power and torque of the propulsion system; therefore, an adequate estimation of aerodynamic parameters is very important for controlling aerodynamic vehicle parameters.

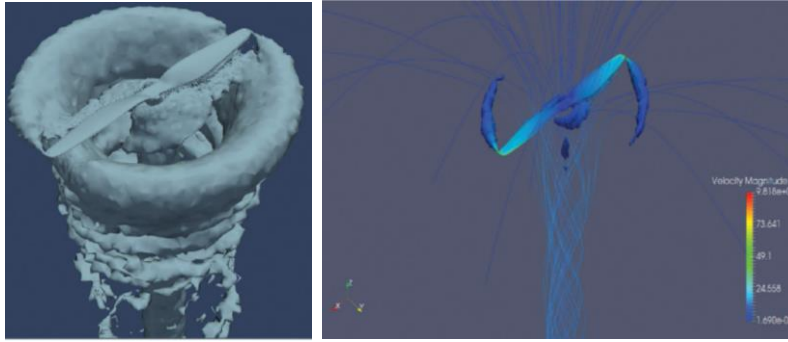


Fig. 5. Swirls created by a single propeller

Computerized simulation of air streams created by 4 rotors indicates the following results (Seokkwan Y, et al, 2016): while the top and bottom left rotors are rotating counter clockwise, the top left and bottom right rotors rotate clockwise. This direction of rotation is typical for quadcopters. Take note of the step-up intake of whirls above the rotors.

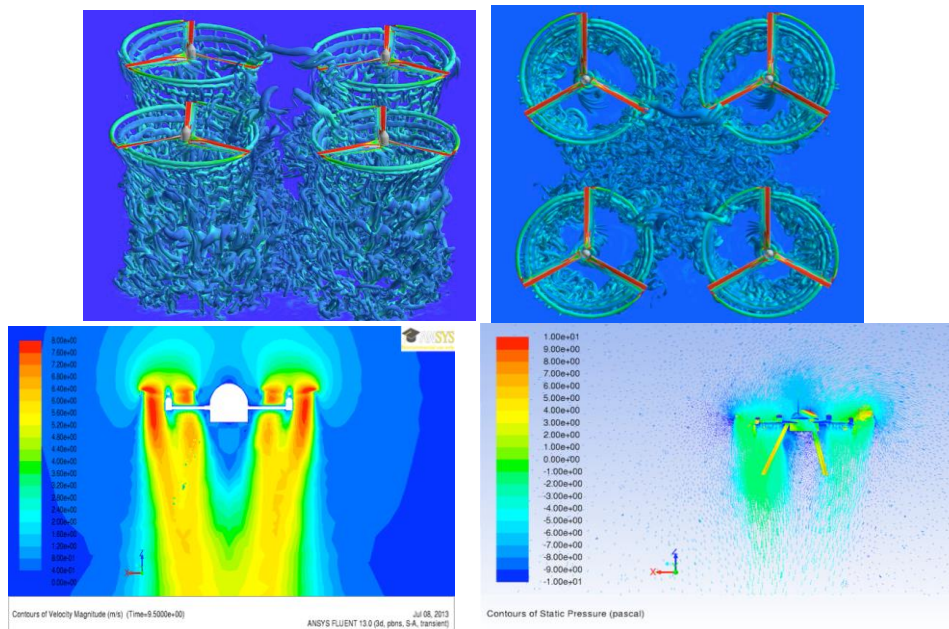


Fig. 6. Simulation of whirls created by drones. a) lateral view b) top view c) simulation performed in ANSYS regarding velocities generated by propellers d) simulation of pressure generated by drones

This phenomenon was not observed in isolated rotors. A top view in fig. 6 b), c) show significant interactions of the turbulent flow between rotors. Streams up between the rotors can be dragged to the centre. (Patrick et al 2014).

A computational study of the interactive aerodynamics of multi-rotor flows revealed that the separation distance rotor has a significant effect on the vertical force of a hover quadrotor. As the separation distance between the rotors becomes smaller, the efficiency of the quadrotor system decreases. While the fuselage creates little force, it seems to have a positive effect on the rotor efficiency by limiting the interaction between the rotor steps.

### 3. Possibilities of using civil drones to measure atmospheric air emissions

According to environmental law, any human activity that generates a significant environmental impact is subject to assessment of environmental impact procedures. In this sense, for acquiring the environmental permit, competent authority requires a specific environmental study to analyze the impact of project implementation.

Among the specific environmental protection studies, we mention: environmental report (RM), assessment report of environmental impact (RIM), the environmental review (BM), and security report (RS), location report (RA) and adequate assessment (EA).

Within the procedures for environmental impact assessment (RIM, BM and RM) environmental authority also requires measurements for air, water, soil, in order to know their level of pollution (initial state).



Air quality measurements at a polluting unit should focus on stationary / fixed sources of emissions that generate large quantities of hazardous gases to human health and the environment.

Choosing sampling points at a stationary source (chimney, canal, and pipeline) should be performed in a manner that distribution of pollutants (gas, dust) in source section is homogeneous and speed, temperature and pressure are as stable as possible.

In order not to influence the quality of measurements, the effluent flow (air gas) must have, as much as possible, a laminar flow, presence of deviations, fittings, fans being avoided as possible.

For measuring stationary sources, reference standard SR EN 15259/2009 "Air quality - Measurement of stationary source emissions. Requirements for measured sections and sites, measurement plan and report" as well as SR ISO 9096/2005 indicating the number of sampling points depending on the outlet section of the source and placement of these points must be observed.

For sampling exhaust gases from stationary source (chimneys) there must:

- exist a proper visiting (access) hole in the chimney, for the sampling probe;
- the measuring equipment must be power supplied;
- gas flow must be laminar and without turbulences.

There are situations when the chimney doesn't have a sampling orifice or doesn't have a work platform placed at the proper height (recommended by legislation).

There are also situations when the stack is 30-50 m high so that makes sampling flue gases impossible.

To perform gas measurements at large combustion plant chimneys, having high air flow rates and large sections, by using drones, some safely recommendations/conditions must be observed, namely:

- Drone usage must consider the reduced autonomy of equipment (max. 40 min. depending on drone load weight and battery);
- Knowledge of exhaust stacks height so that the vehicle is able to reach in time to mediate gas concentrations;
- Knowledge of exhaust gas speed and temperature, because drones can be used at temperatures up to 600C and a maximum wind speed of 40 km / h;
- Handling equipment should be made so as to avoid its damage or deterioration;
- Areas where there are high voltage wires should be avoided to eliminate risks of dropping the vehicle;
- Wind speed should not exceed 40 km / h to not influence stability of the drone, and to not cause significant turbulence during measurements.

Therefore, undertaking experimental measurements at high stationary sources without working platform or having inaccessible platforms would be useful, so that personnel conducting measurements is not exposed to risk of injury (Figure 7).



Fig. 7. Flying the drones in the area of a flare

Using a drone for emission measurements presents a number of dangers and disadvantages as well:

- The presence of toxic gases, hot, flammable dust and noise;
- Equipment short-circuit or static electricity;
- Flow rate of gas in the chimney should not be too high to not affect the stability of the drone, and to not cause significant turbulence during measurements, etc.

Other possibilities for emissions and immissions measurements with the use of a drone equipped with appropriate equipment can be:

- measurements of fugitive emissions through leaks (doors, windows) around industrial houses;
- measurements of immissions in certain locations within the perimeter of industrial units and at the border of their premises;
- methane detection in landfills;
- odour emission detection;
- leakage detection along gas pipeline lines for technical expertise
- measurements obtained can be used to plot dispersion maps with the AUSTAL software, and so on;
- leakage detection along oil pipeline lines;
- methane from waste disposal;
- odour emission, etc.

#### 4. Conclusions

Performant drones can be equipped with sensors for measuring concentrations of gases from stationary sources or environment, with camera and GPS to overfly polluted areas or to monitor qualitative air parameters in protected areas, but it is necessary to consider the whirls formed by their propellers.

If drones will be used to measure concentrations of toxic combustion gases in the emission chimneys of large combustion plants, they eliminate the danger for personnel who has to monitor such chimneys (inaccessible platforms, high heights).

In view of the institute's experience in the field of environmental studies, it would be advisable, to carry out experiments on the use of drones for emission and immissions assessments in ambient air, within a research project.

The following steps must be taken in order to use drones for measurements of emissions and immissions of gases at stationary sources:

- obtaining the license to carry out drone flight exercises,
- flight experiments to be carried out in an equipped training facility in which sources of gas emissions are created,
- within the experiments to gradually perform exercises at different heights with different objects of different shapes, sizes and weights to test the drone's transporting potential,
- based on these experiments, a device for gas measurement, having a suitable weight and sensitivity shall be found and purchased,
- appropriate measures must be taken to protect the measuring device against whirls formed by drones, gas emissions from funnels and wind speeds,
- gradually carry out flight exercises with the drones equipped with measuring devices close to small, medium and large stationary sources.

Also based on research conducted abroad as well as on the experience of INSEMEX Petroșani in performing expertise in the event of explosions and fires generated by explosive gases, the use of drones can be a great support in the research activity of these events.

#### Acknowledgements

This paper was developed within the Nucleu-Programme, carried out with the support of MCI, project no. PN-18 17 01 01 "Developing the institutional capacity to carry out technical expertise of events such explosion / fire".

#### References

- Andres Mauricio Pérez Gordillo, *Comparison between Semiempirical and Computational Techniques in the Prediction of Aerodynamic Performance of the Rotor of a Quadcopter*, IntechOpen, Aerial Robots - Aerodynamics, Control and Applications, pp 82-84, (2017).
- Patrick Y. Haas, Hepia; Christophe Balistreri, Hepia; Piero Pontelandolfo, Hepia; Gilles Triscone, Hepia; Hasret Pekoz, Pierre and Marie Curie University; Antonio Pignatiello, University of Bologna, *Development of an unmanned aerial vehicle UAV for air quality measurement in urban areas*, 32nd AIAA Applied Aerodynamics Conference, AIAA AVIATION Forum, pp 6-7, (2014).
- Patrick Neumann, Victor Hernandez Bennetts, and Matthias Bartholmai, *Adaptive Gas Source Localization Strategies and Gas Distribution Mapping using a Gas-sensitive Micro-Drone*, BAM Federal Institute for Materials Research and Testing, GMA/ITG-Fachtagung Sensoren und Messsysteme, pp 5 (2012).
- Seokkwan Yoon, Henry C. Lee, and Thomas H. Pulliam, *Computational Analysis of Multi-Rotor Flow*, NASA Ames Research Center; Moffett Field, CA United States, (2016).

## Quality of the environment - the result of the interaction between technological progress and education

Lazăr Maria\*

*University of Petrosani, University street, no. 20, Petrosani, 332006, Romania*

---

### Abstract

One of the most acute problems of contemporary society, the quality of the environment and, implicitly, the quality of life, is an intense and sustained concern of specialists from all over the world. After nearly two centuries of accelerated industrial development, the issue of ensuring the quality of the environment and of life on Earth is an essential issue for the whole society. This paper analyzes the main environmental issues at global and regional level, which not only threaten the quality of environmental components but also the safety of the entire planet. Considering that partial solving (unfortunately, many of the phenomena of environmental degradation are already irreversible) of these problems may result from interaction between technological progress and education in the field, the paper focuses on the importance of applying the best technologies available in various sectors of activity and on the role of environmental education. The paper itself is a synthesis that can become a starting point for analyzing and punctually addressing of many and various aspects such as improving the quality of the environment and slowing down of the environment degradation process.

Keywords: environment, quality, life, technology, education

---

### 1. Introduction

The major environmental degradation began at the end of the eighteenth century, with the first industrial revolution, and has worsened over the last decades. With the entry into the technological age, mankind began to produce and consume more, to improve production, transport and communication systems. Unfortunately, all these achievements, which were designed to provide a higher level of comfort, had and have a boomerang effect on the environment, affecting (sometimes irreversibly) the ecological balance and extremely fragile and sensitive systems that regulate natural processes at the planetary level. The first air pollution measurements date from the beginning of the 20th century, but only in the last decades of the last century the concerns about global environmental issues were intensified.

International environmental institutions and organizations were set up to initiate debates on changing environmental conditions at high-level conferences and symposiums. As a result, the United Nations is setting up the World Commission on Environment and Development with the stated aim of assessing the level of environmental degradation and establishing solutions for a viable development of society in the future. The Commission produced and published in 1987 one of the most important documents to underpin the major environmental decisions, namely the Brundtland Report entitled "Our common future". The report has brought new approaches to environmental issues and the economic development of society in the public space, recognizing that the scale of human intervention in nature is increasing and the physical effects of these interventions go beyond national borders. Also, the report states that in many regions of the world there are major risks of irreversible environmental degradation (Report of the World Commission on Environment and Development - Our common future, 1987). The report introduces the concept of sustainable development, respectively *„sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs”*.

Taken at the Rio Conference (1992), this concept supported by three pillars (social, environment, economy), would be detailed and implemented through the Agenda 21 document. The main criticisms of this concept relate to its contradictory objectives, respectively economic expansion, environmental protection, poverty eradication and the free market (Fernando, 2003; Hove, 2004), but also relative to the vague manner in which the ways to solve these goals are

---

\* Corresponding author. Tel.: +40742153709  
E-mail address: MariaLazar@upet.ro.

described. The present paper aims to show that it is essential to pay more attention to the state of the environment, primarily by adding two new pillars for sustainable development, namely technological progress (using best available techniques) and education.

Following the unresolved issues of the Brundtland Commission's main proposal, the United Nations adopted in 2015 the resolution "Transforming our world: the 2030 Agenda for Sustainable Development" setting out a set of 17 objectives and 169 tasks, including deadlines for their achievement. The Declaration states the universal and international character of the implementation of the objectives, but also the fact that "*each state has and exercises free sovereignty over all its wealth, natural resources and economic activity.*" The proposed objectives cover a whole range of global problems faced by mankind, from poverty eradication to ensuring education, health and environment conditions for each person.

## 2. Relationship between environmental quality and quality of life

Environmental quality can be defined as the state of the main environmental components, which can be expressed at a given moment through a series of quantitative and/or qualitative indicators that relate to different standards. The quality of life is difficult to define, its significance being often reported in two dimensions: a psychological one (the inner psychological mechanism that perceives the satisfaction of life) and an environmental one (triggering the inner psychological mechanism) (Greyson and Young, 1994). As a result, it can be said that, in fact, the quality of the environment is one of the most important components of the quality of life.

Because it significantly influences the quality of life, the quality of the environment is a key factor in assessing the well-being of the population (Holman and Coan, 2008). The characterization of the quality of the environment is quite difficult to achieve because there are a large number of indicators to be analyzed. For this reason, it is necessary to establish a set of indicators that are relevant in the context of the analyzed environmental aspects.

In essence, the indicators with a major importance in determining how life quality is affected by environmental degradation are: the exposure of the population to various forms of pollution, access to resources, access to infrastructure and environmental services, land degradation and other natural resources, loss of biodiversity.

EUROSTAT provides statistics on quality of life in the European Union in the online publication *Quality of Life Indicators*. A set of nine indicators, which can be statistically measured and which relate to a range of facilities to which the population needs to have access to meet their own well-being requirements, is used for this purpose. The used indicators include living conditions, health, education, recreation and social interactions, the natural and anthropic environment. In the context of this paper, two of them will be presented, namely education and the environment.

*Education* is, in general, an important component of each country's economic growth, the engine of technological innovation and productivity, with a major impact on the quality of life of individuals. Absence of skills and competences limits access to the labor market and economic prosperity, increases the risk of social exclusion and poverty and can prevent full participation in public, economic and civic actions. Education enhances people's understanding of the world they live in, and therefore the perception of their ability to influence its course.

According to EUROSTAT data, although in Romania the percentage of the population with higher education approaches the EU average, paradoxically, the early school leavers rate is very high and exceeds the targets set for 2020. It is quite clear that over the last decade a large part of the Romanian population has migrated and the country's economic problems lead to school leavers not only early, but also in the higher education cycles. As a result, the number of specialists in different fields, including environmental protection and engineering, is declining, which is already reflected in many sectors of activity.

*Environmental conditions* have a decisive impact on the quality of life, especially as a result of pollution, land, water, landscape degradation etc., causing worsening of the population's health and/or reducing the value of the area or the property in which they live. According to EUROSTAT data, Romania belongs to the category of countries where the population has a high exposure to pollution and other environmental problems, exceeding the European Union average.

It can be seen that the level of exposure of the population to environmental problems is comparable to that of countries such as France and Italy, over Spain, Portugal, Poland, the Czech Republic, Slovakia and well above that of Great Britain and the Scandinavian countries, under the conditions where industrial activities in Romania are much lower. Possible causes for this are: intense pollution from urban agglomerations, as a result of the increase in the number of cars, especially second hand vehicles; small-scale application of agricultural good practice; massive deforestation in recent decades, delay of programs for equipping thermal power plants with facilities for emission reduction.

Given that Romania has committed itself to implement the 2030 Agenda objectives, sustainable development is part of the Romanian public policy, academic and civil society circles. Moreover, the Ministry of Labor and Social Justice has recently recognized a new profession, namely Expert in Sustainable Development, and aims to have a group of experts in the field in all public institutions (Romania's Voluntary National Review, 2018). This forces us to believe that in the future all environmental engineering specialists will be involved by the authorities in solving environmental pressures that will affect the quality of life of the population.

### 3. Main environmental issues and improvement solutions

The process of degradation of the environment is today indisputable, and the major causes of this degradation include anthropogenic activities. Modern society's efforts to improve its living conditions, particularly intensified during industrialization, paradoxically threaten the safety and quality of life on the planet that hosts us. The negative effects of various human activities are manifested both globally (greenhouse effect, climate change, acid rain, ozone depletion, atmospheric pollution) but also at regional and local levels (water pollution, pollution and degradation of soil, biodiversity loss, degradation of the landscape) (Lazăr and Dumitrescu, 2006).

The main driver of worsening environmental problems can be considered the demographic explosion of the last 50 years. Basically, the world's population has doubled during this period. If in 1967 the planet was inhabited by about 3.55 billion inhabitants, in 2018 the world population exceeds 7.6 billion, and the forecast by UNEP shows a population growth trend towards 10 billion in 2050 (Figure 1).

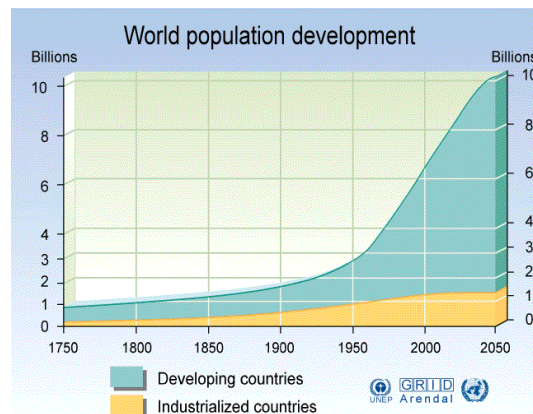


Fig. 1. World population development between 1750 and 2050

Almost 80% of the world's population lives in less developed countries where the environmental pressures are major. Overpopulation is an increasingly prevalent concept, and according to the Global Footprint Network - Advancing the Science of Sustainability, the global ecological footprint is 1.7 planets (Figure 2).

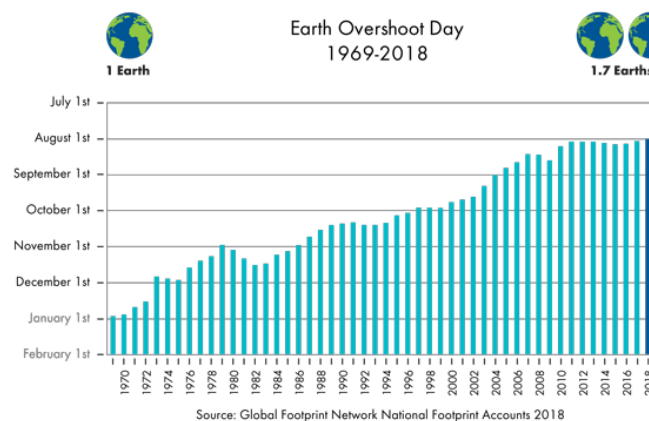


Fig. 2. Overpopulation and resources depletion

Earth Overshoot Day marks the date all of humanity have used more from nature than our planet can renew in the entire year. This date has moved from late September in 2000 to August 1 in 2018.

The exponential growth of the population has as effects increasing demand for land, food and industrial products, mineral resources, increasing transport, increasing the amount of waste to be managed. All these require the intensification of economic activities in different sectors and leading to major pressures on the natural environment. The result of these pressures is represented by different forms of impact at local, regional and global level.

The major challenge of contemporary society is, in particular, to significantly reduce emissions of pollutants into the atmosphere. These emissions generate a global impact such as greenhouse effect, global warming and climate change (carbon dioxide, methane, nitrous oxide, water vapors); destruction of stratospheric ozone (compounds containing chlorine and bromine atoms); acid rain. Such emissions also have natural sources, but they result from most anthropogenic activities. Worldwide, researchers are increasingly concerned with finding effective environmental protection technologies, especially with regard to the atmosphere. Some of the possible solutions for reducing the environmental impact generated by the main sectors of activity are presented in Table 1.

Table 1. Solutions to mitigate environmental impact

Activity sector	Environment friendly technologies
Mining	<p>Using mining simulators to increase productivity</p> <p>Introducing new technologies to replace drilling and explosive operations (surface mining machines)</p> <p>Use of energy from renewable sources and zero emission equipment</p> <p>Innovative waste and water treatment processes from mining</p> <p>Use of methane and carbon dioxide capture and storage technologies</p> <p>Protection of deposits and recycling of mineral resources</p> <p>Ecological rehabilitation of degraded land</p>
Energy production and transformation and other industrial activities	<p>Pond technology - capture of carbon dioxide from fossil fuel combustion processes (valid for all industrial sectors) and pumping into a photobioreactor, where under the influence of LED-generated light result biomass from algae used to produce biofuels, biochemical substances, fertilizers (Applegath, 2016)</p> <p>Use of clean power generation technologies (wind, solar, hydro, geothermal, fusion power plants, etc.)</p> <p>Intelligent energy storage systems</p> <p>Use of fossil fuels with low sulfur content, coal and flue gas desulphurisation</p> <p>Reducing nitrogen oxide emissions by: using burners which combine the fuel with air for a step by step combustion, flue gas recirculation, selective catalytic and non-catalytic post-combustion reduction using ammonia</p> <p>Reducing the use of chemicals that destroy stratospheric ozone</p> <p>Optimizing power generation and supply networks</p> <p>Programs for the reduction, recovery and recycling of waste from all industrial activities</p> <p>Use of the best available technologies in all industrial sectors</p>
Transport	<p>Electric cars with more efficient battery charging technology</p> <p>Intelligent systems to avoid traffic congestion in cities</p> <p>The on-board distillation system, designed and patented by the University of Texas at Austin College of Engineering and Ford Motor Company, which acts as a miniature oil refinery under the hood, not only reduces pollutants generated by hydrocarbon burning but promises to reduce by 80% all exhaust emissions from vehicles.</p> <p>Use of hydrogen fuel cell vehicles</p>
Agriculture	<p>Substantial reduction in the use of fertilizers and pesticides</p> <p>Larger introduction of organic farming</p> <p>The shift to more extensive forms of agriculture, and the application of innovative production methods</p> <p>Use of good agricultural practices, compatible with the requirements of environmental protection and natural resources and landscape</p> <p>Temporary removal of land from agricultural circuit and its use for the purpose of environmental protection</p> <p>Soil conservation and crop rotation</p> <p>Conservation of natural forests and ecological rehabilitation of degraded land through afforestation with endemic species</p> <p>Preventing biodiversity loss by protecting and restoring habitats</p>
Urban development	<p>Use of ecological building materials</p> <p>Implementing the concept of "intelligent city"</p> <p>Ensuring the preponderant energy from renewable resources</p> <p>The orientation of buildings in relation to the cardinal points and dominant winds and the use of vegetation, trees to obtain wind, thermal, noise and air quality protection.</p> <p>Using the best design techniques (the environmental implications should be seen not only in terms of the use of the various available materials, but also of the exploitation and maintenance)</p>

The implementation of environment-friendly technologies can lead to the goals of sustainable development of modern society, so that environmental risk can be reduced to an acceptable level. These solutions are known and applied in many of the developed countries in terms of investing in research and technology. But as long as these countries do not really support countries with a lower level of development, global threats will remain alarming.

#### 4. The role of education in the process of improving the quality of the environment

In the context of worsening environmental quality at all levels (local, regional and global), environmental education is becoming increasingly important and relevant to attempts to protect and improve the state of the environment.

In principle, environmental education is a process of recognizing values and clarifying concepts in order to develop skills and attitudes necessary to understand and appreciate the interrelatedness among man, his culture and his biophysical surroundings (IUCN, 1971). Environmental education also entails practice in decision-making and self-formulating of a code of behavior about issues concerning environmental quality (Martin, 1975).

Today, the environmental education focuses on investigating the conditions and learning processes that enable citizens, young and old, to develop their own capacity to think critically, ethically, and creatively in appraising environmental situations, to make informed decisions about those situations and to develop the capacity and commitment to act individually and collectively in ways that sustain and enhance the environment (Stevenson et al., 2013).

Environmental education involves an interdisciplinary approach to environmental issues, including knowledge from a wide range of fields: mathematics, physics, chemistry, earth sciences, biology, engineering, economics, sociology, etc. Among the main objectives of environmental education are: awareness, knowledge and recognition of environmental issues, training of attitudes and skills in the field, development of assessment and solution skills, participation in the implementation of solutions (Figure 3).

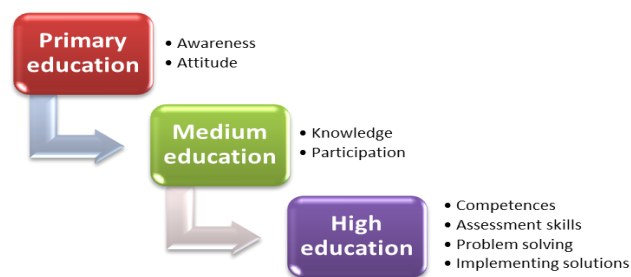


Fig. 3. "Cascade" of environmental expert training

Environmental education is more than just informing the population about environmental issues. If we look at the education system as a whole, namely from the family, the pre-university education up to the three cycles of higher education (bachelor, master, doctorate), a clear distinction can be made between information and specialized education.

*Information on environmental issues* must lead to knowledge, empowerment and the adoption of appropriate individual behavior to protect the environmental components. This information has to be started in the family and continued in an institutionalized way within the primary cycles. Among other things, it aims at raising students' awareness of environmental issues and determine them participate in volunteer actions of protection (greening, recycling, tree planting, etc.).

Given that some of the population that has already passed school age is little or no knowledgeable in this area, local authorities have a number of mechanisms to empower people of different ages (information actions, flyers, organizing seminars, initiating voluntary activities, etc.).

*Environmental education* starts from high school and is continued in higher education.

High schools offer a number of specializations in the field of the environment and their graduates are skilled technicians in various types of environmental interventions (technical support for natural resource management, environmental protection, industry, agriculture, forestry and forest management). Graduates can continue their professional training by attending university courses in specializations dedicated to environmental engineering or Earth sciences.

Higher education offers three cycles of environmental engineering training, namely bachelor, master and doctoral degrees. The environmental engineer is a specialist with a complex and multidisciplinary training that uses engineering concepts to manage and improve the environment but also to find innovative solutions for carrying out economic activities with minimal impact on the environment. Among the many abilities acquired by such a specialist are complex understanding and integrated approach to environmental issues, analysis and interpretation of environmental degradation phenomena and processes, identification, estimation and evaluation of the effects of anthropogenic activities on the environment, design and implementation of solutions for improving the quality of environmental factors, the application of communication principles and methods for the promotion of environmental projects.

In Romania, at present there are specializations in the field of environmental engineering in almost all universities, adapted to their specifics. Although the study programs are similar to those in developed countries, the integration of graduates into the labor market and the implementation of acquired knowledge are relatively difficult, given the lack of adequate know-how and a low level of awareness of environmental issues by a large part of the population.

In order for the specialized education to be effective and the graduates to be able to apply their knowledge, it is absolutely necessary to have a correlation between the labor market and the education system and good communication and collaboration between the line ministries, employers and universities.



## 5. Conclusions

At a time when environmental issues are becoming more and more stringent, mankind is forced to change its current development paradigm. The legislative and organizational framework is established through several international environmental organizations that have set out the directions for action to secure the future of the planet and future generations. Global environmental problems such as global warming and climate change, human health and ecosystem problems, massive pressures on the natural resources of the planet require contemporary societies to find another way to meet their needs and living standards. As we speak of evolution at the economic and social level, the solutions to these problems must be sought by specialists through research, innovation and technology transfer. Implementation of the results may lead at least to an improvement in the environmental conditions and to slowing the natural imbalance processes generated by the accentuated industrialization. To address the major issues relating to the protection of the environment as a whole and its components, education plays an important role in this context. From awareness of environmental issues to assessment and implementation of new technologies, education provides access to information, skills and competences. Thus, it can be argued that improving the quality of the environment and implicitly the quality of life lies at the intersection between education and technological progress.

## References

- Applegath, C., *A new technology that eliminate the CO<sub>2</sub> emissions that cause climate change*, Symbiotic Cities Network, (2016).
- Fernando, J. L., *The power of unsustainable development: What is to be done?*, The Annals of the American Academy, 590, 6-31, (2003).
- Greyson, L., Young, K., *Quality of life in cities: an overview and guide to the literature*, The British Library, London, (1994).
- Holman M.R., Coan T.G., *Voting Green*, Social Science Quarterly, 89 (2008)
- Hove, H., *Critiquing sustainable development: a meaningful way of mediating the development impasse?*, Undercurrent Volume I, No 1, (2004).
- Lazăr, M., Dumitrescu, I., *Human impact on the environment*, Universitas Publishing House, Petrosani, (2006).
- Martin, G.C., *A review of objectives for environmental education*, In G. Martin & K. Wheeler (Eds.), *Insights into environmental education*, Edinburgh, UK: Oliver & Boyd, (1975).
- Stevenson, R.B., Brody, M., Dillon, J., Wals, A.E.J., *International handbook of research on environmental education*, Routledge, New York, (2013).
- \*\*\* Report of the World Commission on Environment and Development – *Our common future*, (1987).
- \*\*\* Romania's Voluntary National Review, 2018.
- \*\*\* International Union for the Conservation of Nature (IUCN), (1971).
- \*\*\* Minister of Environment, *Transformation towards a sustainable and resilient Romania. Romania's Voluntary National Review*, Bucuresti, (2018).

## Equipment for water ozonation in fish breeding lakes

Andrei-Cristian Lupu<sup>a</sup>, Marius Petrescu<sup>b\*</sup>

<sup>a</sup>University of Agricultural Sciences and Veterinary Medicine, Iași, Aleea Mihail Sadoveanu no. 3, 700490, Romania

<sup>b</sup>Petroleum-Gas University of Ploiesti, Bd. București no. 39, 100680, Romania

---

### Abstract

The invention that is presented in the paper refers to the procedure for the ozonation of waters in the fish lakes. It thus combats the phenomenon of eutrophication due to accidental spills of organic substances, overheating of water attributable to climate change, and also the improvement of water quality, which is very necessary for the proper development of fishing activity.

*Keywords:* ozonization, eutrophication, fish

---

### 1. Description

The paper deals with the ozonation of water from fish ponds in order to eliminate the eutrophication phenomenon due to accidental spills of organic substances, excessive water warming attributable to climate change or to improve the quality of water, a very necessary development of fish farming.

Eutrophication is one of the most challenging environmental problems that the surface water bodies are facing in present time (Smith, 2009; Li Kun et al., 2017). Eutrophication is an ecological process, similar to aging, in which a water body is increasingly enriched with essential nutrients of the aquatic plants (Rast, 1996) which results in increase of the primary productivity, i.e. rate of photosynthesis of the aquatic ecosystem (Qin et al., 2013). The most common signs of eutrophication in lakes and rivers involve heavy algal blooms resulting in high turbidity and anoxic conditions in the deeper parts of the waterbody due to the decay of detritus which leads to fish kills (OECD, 1982; Wang, 2009). Eutrophication may lead to severe health hazards to human and animals through various pathways. It is a major health threat if drinking water is collected from eutrophied water body. Eutrophication also results in serious ecological problems as well as have impact on the aesthetic view and economy.

To address the undesired effect of chemotherapeutants in aquaculture, ozone has been suggested as an alternative to improve water quality. To ensure safe and robust treatment, it is vital to define the ozone demand and ozone kinetics of the specific water matrix to avoid ozone overdose (Aikaterini et al., 2018).

Devices for surface water aeration are known by paddle, winding, driven by internal combustion engines mounted on pontoons, boats or rafts.

It is also known an installation which distributes the ozone-enriched air through some pipes provided with holes mounted on some supports entwined in the agglomerate layer.

Still other methods are known, such as the use of motor boats that have the same role of winding by breaking the fat film that forms over the water in organic spills.

These methods and installations have several disadvantages, such as:

- the introduction into the aquatic environment of vibrations in the form of sounds, infrasounds which present discomfort to fish and other aquatic creatures;
- the introduction into the water of hydrocarbons resulting from internal combustion engine cooling systems;
- repeated failure of the aeration ducts due to blocking the holes by detaching them from the supports on which they were mounted in the agglomerate layer;
- level variations due to hydrostatic pressure influence the volume of ozonized air introduced into the water of the lake.

The device for ozonizing water in the fish ponds consists of two unconventional energy sources mounted on the shore of the lake consisting of a vertical wind turbine group and a solar panel with solar panels with known cooling

---

\* Marius Petrescu. Tel. 0725 443 700  
E-mail address: marius.petrescu@gmail.com

systems for active surfaces, thus obtained is stored in a space containing a group of accumulators, energy which is then distributed to some modules, a module consists of a device for obtaining the filtered and compressed air passing through a Venturi tube is mixed with the ozone produced by some ultraviolet generators ( $\lambda=185\text{ nm}$ ) by a known method, after which, by means of another special construction module, it is distributed in the water of the basin or the lake, and for the protection of fish against ihtiphage birds, the distribution system also contains permanent magnets mounted on the surface of the rotating distributor due to the reactive effect of the air exhausted in the lake water creating a discomfort to the birds due to the change of the magnetic field, the birds being confused, leave the area where the lake or basin is located, and in order to provide a protection against theft, this water ozonation facility also contains some GPS circuits for signaling site change at installation, audible, luminous, and presence of malicious people especially when the installation is mounted on the shores of the lake.

The paper has the following advantages:

- the occurrence of the phenomenon of eutrophication is excluded;
- improve water quality and the conditions of fish species development;
- achieves the best performance with regard to the distribution of the ozonized air in the water with its winding;
- due to the disturbance of the terrestrial magnetic field by the presence of an artificial magnetic field in the installation area, the fishery activity of the ihtiofage birds;
- it does not depend on the variation of the water level, being always positioned at its surface;
- due to the presence in the water of the oxygen atom (O), part of the parasites and bacteria are destroyed;
- if mounted on the shore, it is equipped with GPS circuits and anti-burglary sensors;

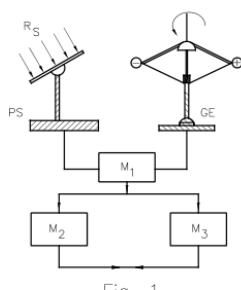


Fig. 1. The overall scheme of the device

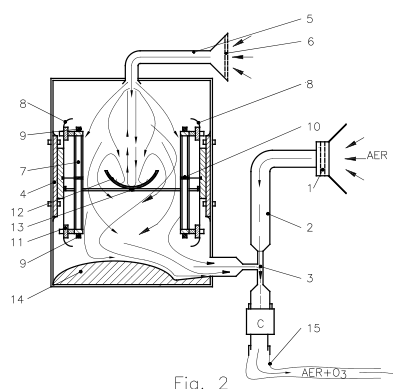


Fig. 2

Fig. 2. Section through the ozone-generating device

The water ozonisation plant consists of an energy module  $M_1$  (Fig. 1) which contains a vertical axis wind group whose active elements for converting the energy of the air currents are aerodynamic cones mounted in such a way that their rotation is in the trigonometric sense (or radial-axial) meaning that coincides with the sense of rotation of the Earth, which is an advantage for increasing the conversion efficiency due to the reduction of friction forces, this phenomenon being little known and applied, and for obtaining energy in cases of meteorological calmness and lack of nebulosity, energy can be obtained using solar cells, the number of which depends on other usage requirements, panels designed to increase the efficiency of cooling systems of the light receiving surface, with cleaning systems for these surfaces and with high-intensity wind protection systems; the ozone system for pools or lakes has a module  $M_2$  containing a compressor C, and if it fails it is replaced by an air turbine TA required to create air intake from the environment that was initially filtered by known means containing the filter group 1 (Fig. 2), after which he enters into a Venturi tube 2, and according to the continuity of flow of fluids through the pipes, a suction of the ozonized air in the narrow pipe is carried out 3 due to the drop in static pressure  $P_s$  and increased dynamic pressure  $P_d$ , the ozone-mixed air is then compressed into the compressor tank, being sent to a distribution module  $M_3$  to be then discharged into the water

of the lake; in the same module  $M_2$  (Fig. 1) the device for ozone generation from the atmospheric air formed by a closed enclosure is also mounted 4 (Fig. 2) where the air is sucked in due to the pressure drop created by the Venturi 2 through the pipeline 5 after being filtered by the filter 6 and subjected to UV radiation ( $\lambda=185\text{ nm}$ ) issued by two generators 7 mounted in the focus of an ellipsoidal mirror 8, with the sockets 9 and bracelets 10 and reinforced with supports 11, concave chicanery as a crucible 12 caught on a rod 13 has the role of lengthening the aspirated air beam, thus increasing the duration of UV radiation action, of the ozone efficiency ( $O_3$ ) by decomposition of oxygen molecules ( $O_2$ ) in oxygen atoms (O) and then combining oxygen ( $O_2$ ) with an oxygen atom (O) thus forming an ozone molecule ( $O_3$ ), a reaction similar to those taking place above the stratosphere, a layer that is found after the troposphere; ozone so formed protects us from the other radiation emitted by the Sun; piece of special shape 14 helps with the Coanda effect follow the curve to help the ozone escape into the Venturi tube, and through the flexible pipe 15 (Fig. 2) the air and ozone mixture is driven to a module  $M_3$  (Fig. 1) to be distributed in water.

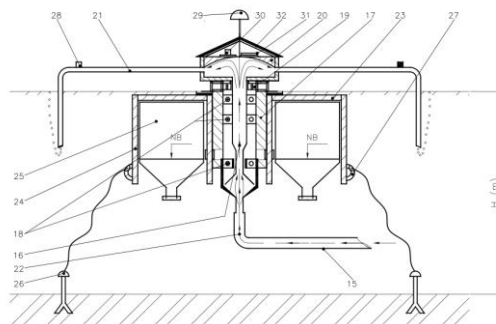


Fig. 3. Section through the ozonization device

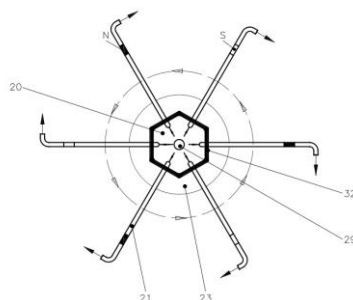


Fig. 4. Above seeing of the distribution device

The module  $M_3$  contains a vertical pipe 16 mounted in a cassette 17 with radial bearings 18 and pressure 19, having another hexagonal shaped box in the upper part 20 having the upper hemispherical wall to ease the air outlet in the pipe 16 to penetrate the water through the pipes 21, which thanks to the construction creates a reaction effect that causes the whole assembly to rotate; the ozone-enriched air enters the pipe 16 through a flexible pipeline 22, and to ensure buoyancy, the whole assembly rests on a circular plastic structure 23 of low density with a circular window in the center in which the box is inserted 17 which contains the bearing system, which allows the distributor to rotate through the reactive effect of the ozonized air at the outlet, the direction of rotation being the trigonometric, identical to Earth rotation, which greatly reduces friction between the water layers during rotation, improving the distribution of ozonized air and water flowing in the installation area, the pipes being curved to allow this; the buoyancy of the device is accomplished by inserting inside the circular structure 23 some niches 24, of some PET containers 25 of different volumes depending on the size of the distribution device and its weight; adjusting the distance to the surface of the water is achieved by introducing a certain volume of water into the PET containers, and to create a pressure inside, a spoon filled with lime powder is placed in each container.

Finally, the device is anchored by the anchors 26 through a plastic thread of the supports 27, and for the protection of fish against birds of different species, on the ozone air distribution pipes 21 some permanent magnets are caught (neodim) 28 which by their presence modifies the distribution of the terrestrial magnetic field in the area of the module location, which creates a discomfort to the birds, leaving the area; the phenomenon is accentuated to most of these things because they are oriented in space by the force lines of the Earth's magnetic field and this change frightens them especially when the disruptive magnetic field is variable due to the rotation of the ensemble, the magnets being mounted with different polarities on the top of the pipes, alternatively.

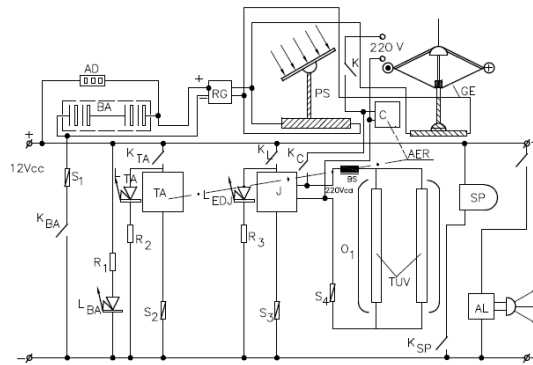


Fig. 5 – Electrical scheme of the ozonozation device

A girofar is used to indicate nighttime operation 29 mounted in the circuit with a battery 30 by means of a twisted electric circuit 31 (connects the girofar in the evening and disconnects it in the morning), these being mounted in the top of the hexagonal cassette 20 on the sides of which are the solar mini-panes 32 to power the battery 30; switch K connects to the network of 220V of the compressor C and the ozone generator when the power of the battery BA falls below projected value due to prolonged weather phenomena (calm and nebulosity).

## 2. Conclusion

This device for ozonizing water in the lakes is made to avoid the occurrence of eutrophication and to improve the quality of water in which various fish species grow and develop are formed, for example, from two conventional sources of energy known in the art, namely a microcentral baffle solar photovoltaic and a vertical axis wind group, the energy accumulated in batteries with accumulators via a regulating relay, which are part of the M1 module, supplying another M2 module, containing the mini-installations for obtaining the air pressure, a turbine, a compressor and the ozone generation device. The plant also contains another M3 module, which is a special device consisting of a counter-rotating distributor due to the reactive effect of the air outlet through some pipes trapped in a hexagonal enclosure, thus achieving a high efficiency in concerns the penetration of ozone into the water of the lake as well as the flow of water.

## References

- Aikaterini S., Rojas-Tirado P., R. K.Chhetri, Kamilla M.S. Kaarsholm, R. M., B.Pedersen, Lars-Flemming, Pedersen, H. R.Andersen, *Ozonation control and effects of ozone on water quality in recirculating aquaculture systems*, Water Research, , pp. 289-298, (2018).
- Brevet RO 127188, Antohi Constantin-Marin, Crăciun Ioan, Giurma Ion, Telișcă Marius, Ro, *Instalație pentru aerarea apelor de suprafață* (2010)
- Li-Kun, Y., Sen, P., Xin-Hua, Z., Xia, L., *Development of a two- dimensional eutrophication model in an urban lake (China) and the application of uncertainty analysis*. Ecol. Modell. 345, 63–74, (2017).
- OECD, *Eutrophication of Waters. Monitoring, Assessment and Control*. OECD, Paris 154 pp, (1982).
- Qin, B.Q., Gao, G., Zhu, G.W., Zhang, Y.L., Song, Y.Z., Tang, X.M., Xu, H., Deng, J.M., *Lake eutrophication and its ecosystem response*. Chin. Sci. Bull. 58 (9), 961–970, (2013).
- Rast, W., Thornton, J.A., *Trends in eutrophication research and control*. Hydrol. Process. 10, 295–313, (1996).
- Smith, V.H., Schindler, D.W., *Eutrophication science: where do we go from here?* Trends Ecol. Evol. 24, 201–207, (2009).
- Wang, H., Wang, H., *Mitigation of lake eutrophication: loosen nitrogen control and focus on phosphorus abatement*. Prog. Nat. Sci. 19, 1445–1451, (2009).

## Plant for improving water quality in juvenile fish ponds

Andrei-Cristian Lupu<sup>a</sup>, Marius Petrescu<sup>b\*</sup>

<sup>a</sup>University of Agricultural Sciences and Veterinary Medicine, Iași, Aleea Mihail Sadoveanu no. 3, 700490, Romania

<sup>b</sup>Petroleum-Gas University of Ploiesti, Bd. București no. 39, 100680, Romania

---

### Abstract

The paper relates to an installation for improving water quality, especially for fish-growing basins of different fish species. Fisheries are required to check for any changes in water quality or fish behavior.

The solution presented in this paper refers to the construction of pools for different fish activities, using materials and constructive forms that ensure good water quality, a clean and healthy environment for the growth and development of different fish species.

*Keywords:* fish-growing basins, fish, water quality

---

### 1. Introduction

The paper relates to a device for improving water quality, especially in juvenile fish breeding pools, existing in fish farms where checks are required to determine possible changes in water quality or fish behavior.

As existing facilities for maintaining the quality of water as a living environment for fish in existing ponds or for other activities, we can mention:

- devices known to refresh water from surface or underground sources using electric pumps;
- winding devices are also known to allow the oxygen to enter the water in pools or where the fish grows;
- there is also known a paddle aerator used in fish cages ponds that helps reduce nonionized ammonia.
- these methods and installations have the following disadvantages:
- noise of aerators or pumps, technological phases that can cause stress on fish with repercussions on the occurrence of diseases;
- are not equipped with recirculating or refreshing water disinfection equipment that may contain bacteria or other micro-organisms that may affect the living environment of the fish;
- consumption of conventional fuels and electricity for the operation of the equipment;
- if the growth ponds are located on the administrative platform in enclosed areas, they are not equipped with earthing sockets, so that the volume of water in the ponds is not connected to the Earth's energy that is beneficial for the fish;
- disinfection equipment with high germicidal ultraviolet radiation and medium flow rates is not used.

### 2. Objective

The problem solved by the work consists in building pools for different fish activities, from materials and constructive forms that ensure good water quality, a clean and healthy environment for the growth and development of different species of fish.

### 3. Description

The work to improve the quality of water in the fish ponds is made up of an ellipsoidal basin to allow natural water movement, and to create her pulse, is mounted in the lower part of the ellipsoid, namely in the outlets of the section, some zinc electrodes connected electrically to a closed / open normal contact of a relay powered by an oscillator, which generates in the pool water pulses of electrons coming from the Earth thanks to a socket (Earth is considered a huge electron generator), also for the achievement of good quality water, the device also contains: an ellipsoidal pipe

---

\* Marius Petrescu. Tel. 0725 443 700  
E-mail address: marius.petrescu@gmail.com

mounted at the top of the basin and provided with holes such that by evaporating the water, which leaks out on the outside of the pool to prevent its heating, but it ensures a drop in the water temperature inside, and important, disinfection of water from time to time for recirculation or filling after it has been discharged at the end of a use cycle, is carried out with equipment generating germicidal wavelength UV radiation known per se in such a way as to allow an important flow of water from underground sources, after it has been filtered beforehand, the water flow in the plant for different technological phases is possible due to valves, valves and a suitable electric pump for the flow rate.

The paper has the following advantages:

- due to the shape of the construction material used, the leakage of water to the outer surface of the basin ensures the maintenance of the natural circulation, the freshness and the water temperature inside the basin;
- due to the electrodes connected to the ground, the water in the basin is connected to the existing water on planet Earth, allowing its pulsation according to the Schumann resonance, eliminating the stress of the fish during growth and storage for valorization;
- allows the disinfection of recirculated water or water at the end of the final phase of the technological cycle for filling the basin from a preferred, underground source;
- ensures good water quality in the basin, thus allowing the growth and development of fish species without major losses.

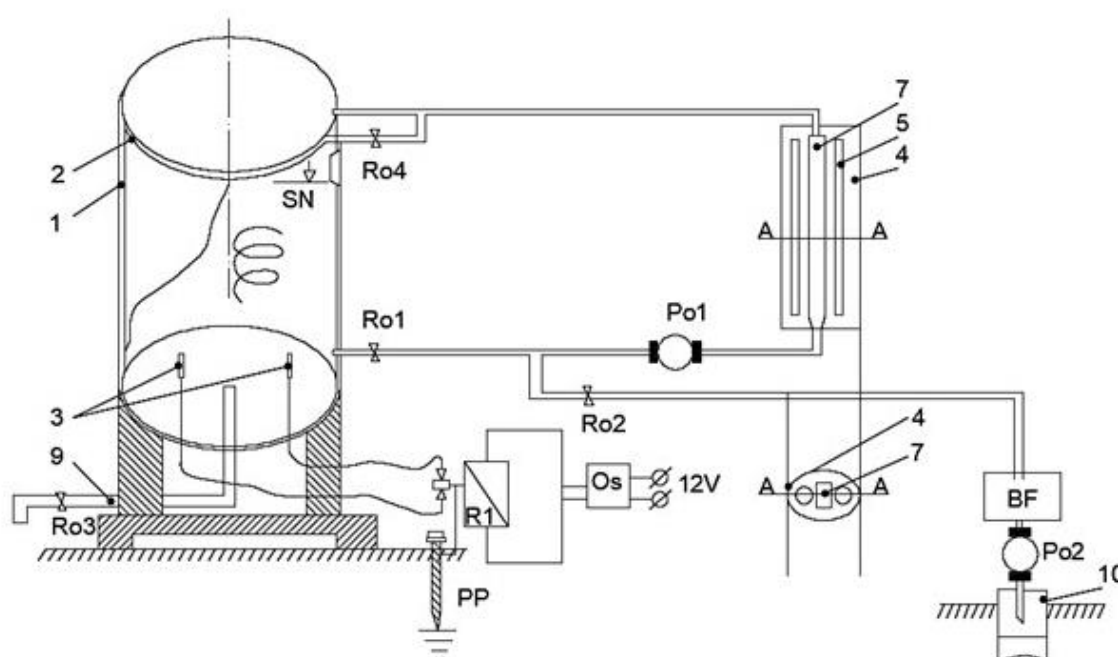


Fig. 1. Technological scheme of the device

The device for improving the water quality of the fish ponds consists of an ellipsoidal basin 1 (Fig. 1), shape that allows natural water movement (along a spiral cycloidal spiral curve) built of special materials for the water inside to "breathe", basin located in an area within the administrative platform of a fish farm, and in order to keep a low water temperature in the basin, a duct 2 provided with small holes, which by opening the tap  $R_{04}$  allows the drainage of the water on the outside of the pool and evaporation causes the temperature of this surface to decrease; it is known that everything that surrounds us on the surface of the Earth is pulsation, vibration and therefore the water inside the pool to pulse at a frequency equal to 7.83 Hz (today 12 Hz) known as the "Schumann Resonance", the lower part of the ellipsoidal basin is pierced by two electrodes 3 connected to the normally open contacts  $1R_1$  and to the normally closed contact  $1R_2$  of a relay  $R_1$ , relay mounted in a feed circuit of an oscillator  $O_s$  whose oscillation frequency is set by programming, the mass of contacts being connected to an Earth socket PP, which determines the occurrence of universal vibration in the volume of water in the basin, thus contributing to the elimination of the stress of the fish while maintaining a normal living environment and normal development; if, following checks, the incidence of diseases is detected due to causes recorded in an analysis report, then by opening and closing of valves  $R_{01}$ ,  $R_{02}$ , recirculate the water in the pool, water passing through a UV radiation disinfection device ( $\lambda=254$  nm) consisting of an enclosure 4 (Fig. 1) with the ellipsoidal edges in the outlets of which are mounted two UV generators 5 and separated by some straight surfaces 6 to create two virtual focal points resulting from UV radiation reflections in the center by the edges of the enclosure, located in a rectangular cavity 7 made of organic glass through which water flows in small whirlpools due to baffles 8 to achieve a high yield disinfection.



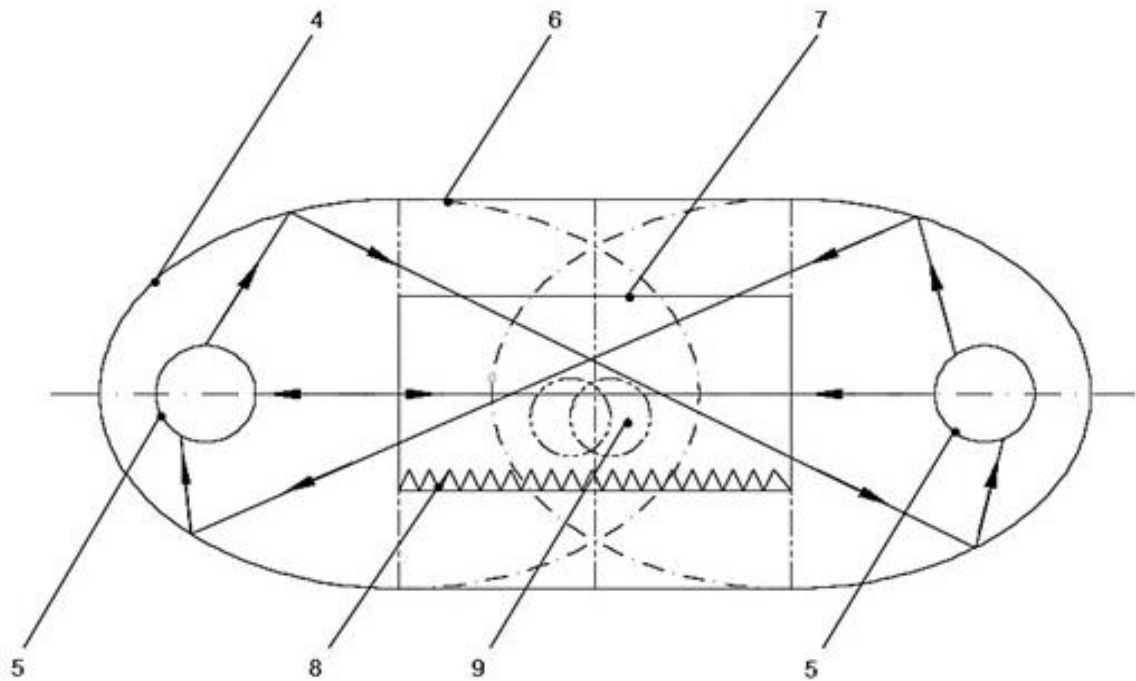


Fig. 2. Section through the disinfection device

At the end of the technological flow when the fish was transferred to the storage and further development basins for fishing or for recovery by transport to the outlets, the basin 1 (Fig. 2) is discharged by opening the valve R<sub>03</sub> mounted on the drain pipe 9, and after washing and disinfection it is filled with underground water from a drilling 10 by pumps P<sub>02</sub>, P<sub>01</sub>, filtered through the filter battery BF, the disinfection being carried out by the disinfection equipment described above, reaching the maximum level is signaled by a sensor SN, after which a new technological stream can begin;

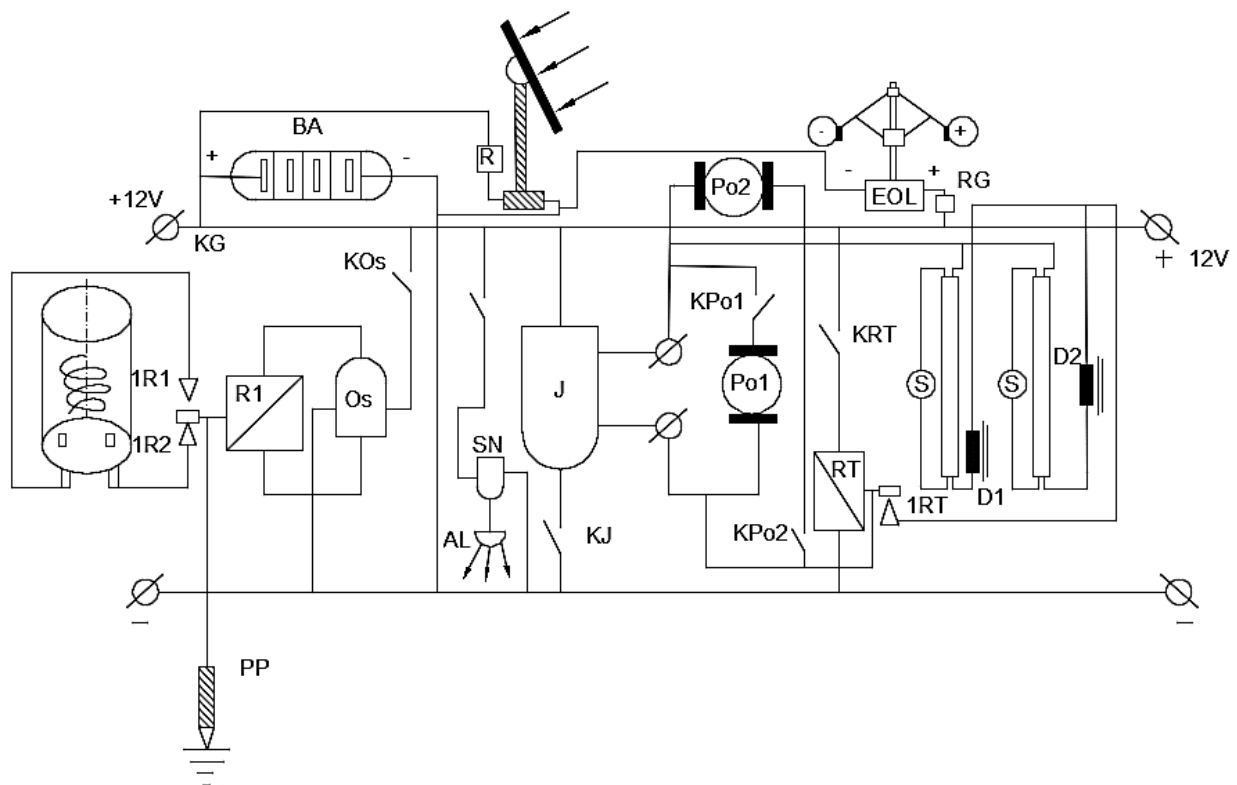


Fig. 3. Electric scheme of the device (tank)

#### **4. Conclusions**

The main circuit schematic diagram (Fig. 3) contains the power supply BA charged from a solar panel under the influence of solar radiation RS and the regulator relay RG or from a wind power plant with aerodynamic cones, then the electrical energy thus obtained feeds the following circuits: the circuit for obtaining the water pulse with the relay R<sub>1</sub> through normally open / closed contacts 1R<sub>1</sub>, 2R<sub>1</sub> through the oscillator O<sub>s</sub>, the warning circuit reaches the maximum level through the sensor SN and the sound alert AL through the switch KO<sub>s</sub>, the power supply generated by the inverter I to the voltage of 220 Vca of pumps P<sub>01</sub>, P<sub>02</sub> through the switches K<sub>P01</sub>, K<sub>P02</sub>, the supply circuit of the disinfection equipment through the switch K<sub>PT</sub>, time relay RT with its normally open contact 1RT and wavelength germicidal UV radiation generators  $\lambda=153,7\text{nm}$  G<sub>1</sub>, G<sub>2</sub> with starters S and drossels D<sub>1</sub>, D<sub>2</sub>, operation of the entire plant is possible by actuating the general switch K<sub>G</sub>.

#### **References**

- Antohi C.M., Staicu D., Stanila A., *Instalație pentru obținerea apei potabile*, Brevet RO 112498, (1993).  
Antohi C.M., Nițescu E., Mitroi A., *Instalație de pasteurizare*, Brevet RO 113800, (1993).  
Antohi C.M., Model de utilitate MU/2012/00150032, (2012).

## Mobile autonomous aerator

Andrei-Cristian Lupu<sup>a</sup>, Marius Petrescu<sup>b\*</sup>

<sup>a</sup>University of Agricultural Sciences and Veterinary Medicine, Iași, Aleea Mihail Sadoveanu no. 3, 700490, Romania

<sup>b</sup>Petroleum-Gas University of Ploiesti, Bd. București no. 39, 100680, Romania

---

### Abstract

The paper presents the model of an autonomously mobile aerator usable, especially in fish farms, for operative interventions in the incipient phase of the eutrophication phenomenon. The equipment provides oxygen intake, especially in the summer days when the water temperature is rising. The use of the aerator reduces the losses due to the death of the fish by suffocation. The proposed aerator variant can also be used in polluted waters as a result of the spillage of organic substances.

Keywords: aerator, eutrophication, fish

---

### 1. Introduction

The paper refers to an autonomous mobile aerator required especially in fish farms for operative interventions in the event of an early occurrence of the eutrophication phenomenon, in order to ensure oxygen intake of the fish especially during the summer days when the temperature of the water is increasing, avoiding major losses that are caused by the suffocation of fish. This phenomenon of eutrophication can also occur if organic substances are discharged into the lake/pond. Most of the freshwater lakes and wetlands are facing the problem of water quality deterioration and ecological imbalance due to the increasing anthropogenic activities particularly in developing countries (Biswajit, 2018).

Methods for aerating waters, lakes of various uses using motorized boats or rowing are known. A paddle aerator is known to be rotated by internal combustion engines (Sanjib, 2002).

Various equipment is known to introduce ozone in the water used to reduce the microbial flora as well as to enrich the concentration of oxygen in the lake water to survive the fish. There is also known a platform used for recreational tourism and for reducing eutrophication of lakes using ozone-driven air jets.

These methods and equipment have the following disadvantages: - the use of internal combustion engines pollutes with hydrocarbons from engine cooling circuits; - engine noise or other sources determines the stress of the fish; - the use of ozone for aeration is a method that has high costs and therefore its use by aquaculture farmers is avoided; - the oxygen port for motorboats or rowing is negligible; - the use of large platforms requires high pressure air jets not being able to move in areas with shallow water.

### 2. Objective

The problem solved by the work consists in the realization of a mobile aerator moving remotely on the water of the lake without the use of fossil fuels while at the same time aerating the water which is accomplished by introducing into the water some jets of air simultaneously with the introduction into the air water jets, all at an acceptable price, although this water shift is remote controlled by radio waves.

This mobile aerator has the ability to overcome the above disadvantages in that it contains a floating support which can be a boat, catamaran, etc. of small sizes that are mounted: for example, two photovoltaic panels, and in the back, side and front there are some air turbines and water pumps, which at a programmed time by a microcontroller or remote control on the shore create some jets of air in the lake water and jets of water in the air that provide remote radio scrolling, as shown above from a distance, obstruction of obstacles by infrared sensors, stopping near the shores through a video camera and returning to the starting point performs automatically by using a known remote control by the user.

---

\* Marius Petrescu. Tel. 0725 443 700  
E-mail address: marius.petrescu@gmail.com

The device has the following advantages:

- performs rapid intervention in the area where a refreshment of water is required;
- can operate throughout a sunny day or night due to the electricity accumulated by solar panels;
- it does not create noise of thermal motors, which due to vibrations produce a continuous stress to the fish and does not pollute the water of the lake;
- by using water jets, in addition to the oxygen intake, a decrease in the water temperature is also achieved due to the evaporation phenomenon;
- the operation of the aerator takes place in a stand-alone mode without conventional power consumption;
- the mobile autonomous mobile aerator can move into shallow water areas, the preferred location for algae development, and its great mobility results in increased aeration efficiency.

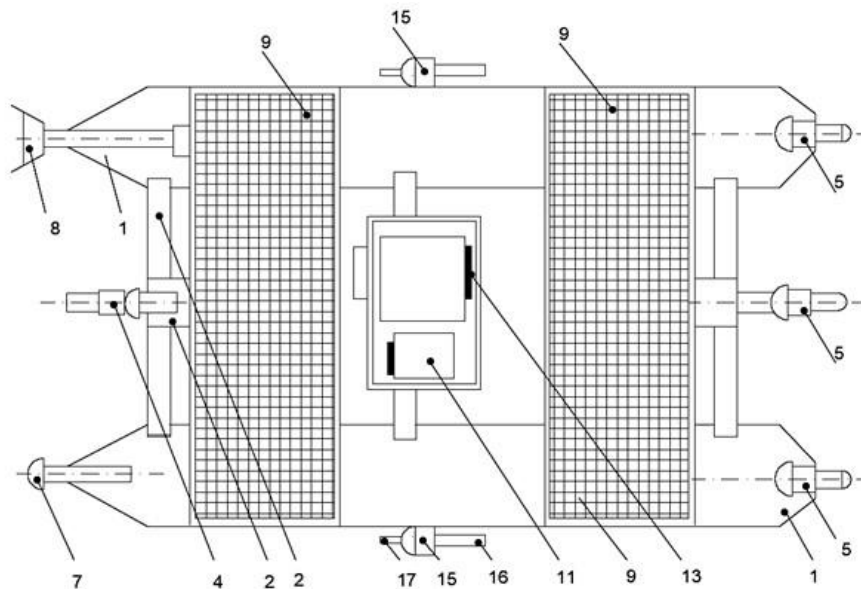


Fig. 1.a. Above seeing of the aerator

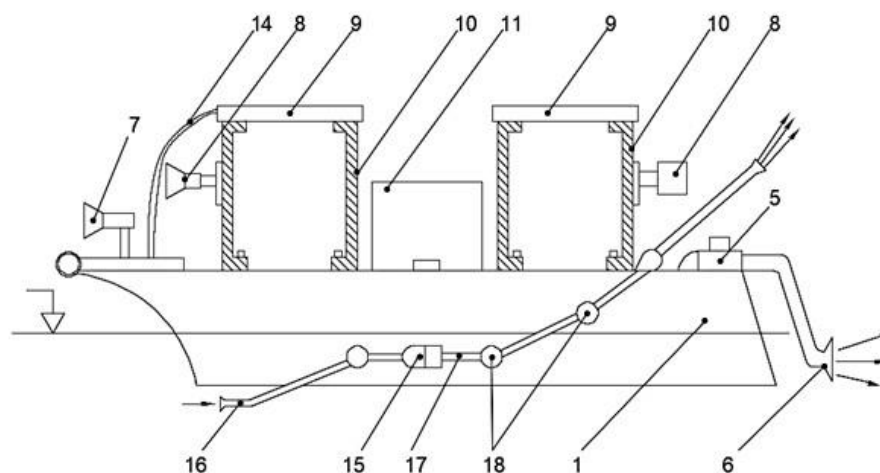


Fig. 1.b. Transversal section of the aerator

### 3. Description

The autonomous mobile mobile aerator is designed for operative interventions in case of oxygen deficiency in the water of some fish lakes and consists of a miniaturized catamaran with two aluminum floats 1 (Fig. 1.a) connected by transversal aluminum latches 2 and longitudinal latches 3, and at their heads they are tapped: an air turbine 4 for stopping and reversing, and three turbines 5 are used for forward travel, the displacement being possible due to the reaction force of the air jet evacuated in the water through the nozzles 6; to avoid collisions with objects floating in lake

water or shoreline, the aerator also contains an infrared sensor 7 and a video camera 8; for autonomous operation of the aerator, two photovoltaic panels are located above the deck of the catamaran 9 attached to the deck by some aluminum supports 10 between which an enclosure is centrally located 11 of the polycarbonate in which the electronic circuits for controlling the remote operation are located, the photovoltaic panel regulator relays and the emulsion battery 12 (Fig. 1.a) caught firmly with the breech 13, and in order to reduce the drag force due to the air flow, a polycarbonate windscreen 14; to increase aeration efficiency, the self-contained mobile aerator also contains two pumps immersed in water 15 (Fig. 1.b) with the sorb 16 and the evacuation nozzle 17 through known plastic rotors 18 necessary to determine the height of the water jet (max 14 m).

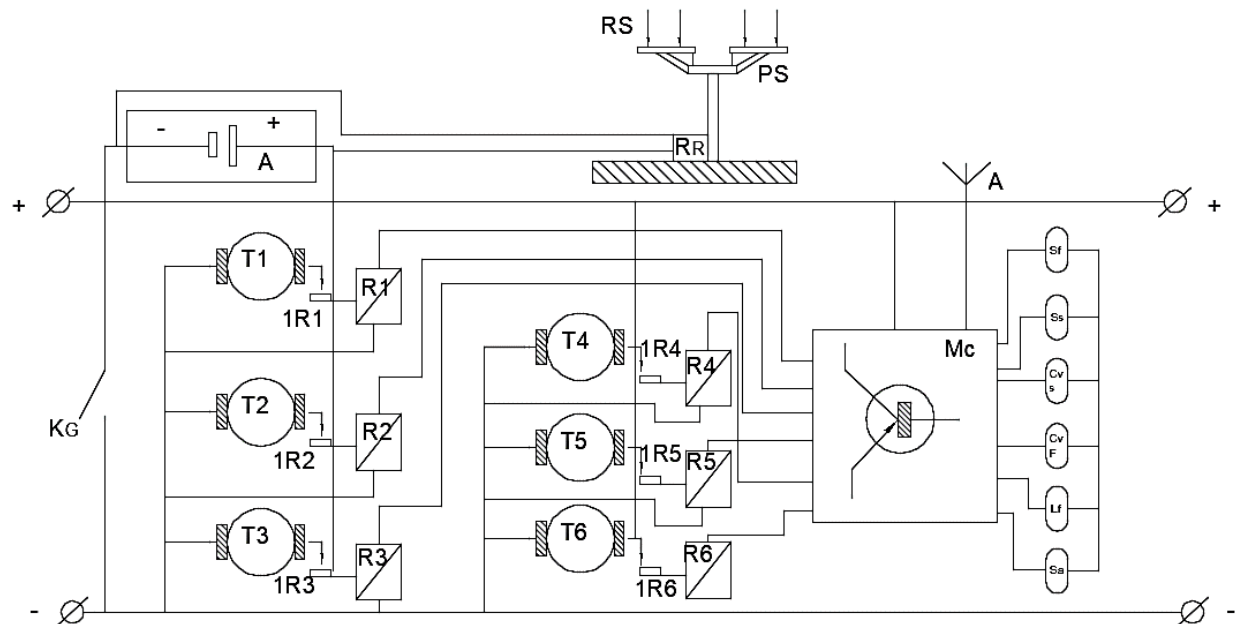


Fig. 2. Electric scheme of the aerator

To increase visibility at night, the aerator is equipped with a headlight 19 which works with a built-in twilight sensor; the electric circuit diagram of the aerator operation contains two photovoltaic panels PS by means of which the solar radiation RS via a regulator relay  $R_G$  is converted into continuous electric current stored in an emulsion battery A, current which is used for the operation of the following circuits at the receiver, namely: the air turbine power supply circuit  $T_1, T_2, T_3, T_4$  through normally open contacts  $1R_1, 1R_2, 1R_3, 1R_4$  of some relays  $R_1, R_2, R_3, R_4$ , the supply circuit of the two medium power submersible pumps (throws water up to the height of 14 m)  $P_1, P_2$ , through contacts  $1R_5, 1R_6$  of some relays  $R_5, R_6$ , circuits that come into operation when in accordance with commands received by radio from the known remote transmitter, which is located on the lake shore, the microcontroller on board the aerator distributes the on-board power supply for turbines and pumps; because the state of the water glare can change by the appearance of floats and the operator on the shore that has the transmitter does not notice, because of distance or other phenomena that impede visibility, the aerator is equipped with sensors whose circuits coupled to a microcontroller on the aerator are: the sensor circuit  $S_F$  (Fig. 2) that senses the front obstruction,  $S_s$  – optional rear obstacle, video camera – front view  $C_{VF}$ , optional rear view camera  $C_{VS}$ , increasing the intensity of the headlight  $L_F$ , and if there is a fault in the electrical circuits through the sensor  $S_A$  an alarm signal is triggered, to take remedial action, requiring for this purpose the movement to the place where the aerator is located and its recovery.

#### 4. Conclusion

Mobile energy autonomous aerator required especially in farms for operative interventions in case of an early occurrence of the eutrophication phenomenon, using for this purpose a catamaran that uses for its autonomous displacement on the lake surfaces the effect of the reaction of some jets of air emitted in water by some turbines and some jets of water thrown under a certain angle into the air by some submersible pumps, these being operated by radio remote control by a shore operator, the required energy being obtained by two photovoltaic panels and stored in a battery accumulated by decks, air jets in the water, and water jets in the air contributing to the increase of the oxygen concentration in the water, which results in eradication of the eutrophication phenomenon, the whole operation is possible due to programming of the two microcontrollers themselves known, one on broadcast and one on reception, operation that can last both day and night due to the unconventional energy stored.

## **References**

- Biswajit B., Kamal U. A., *A review on lake eutrophication dynamics and recent developments in lake modeling*, Department of Civil Engineering, Tezpur University, Napaam 784028, Assam, India, (2018).
- Sanjib M., Mal B.C, Bandyopadhyay S., *Prediction of aeration performance of paddle wheel aerators*, Aquacultural Engineering Section, Agricultural and Food Engineering Department, IIT, Kharagpur 721 302, West Bengal, India, pp.217-237, (2002).
- RO 127188 Antohi C.M., Crăciun I., Giurma I., Telișcă M., *Instalație pentru aerarea apelor de suprafață*, (2010).

# Mechanical processing methods of waste electronic and electrical equipment with special regards to NIR separation

Roland Romenda<sup>a</sup>, Zoltán Virág<sup>b\*</sup>, Tamás Magyar<sup>c</sup>

<sup>a</sup>PhD student, Institute of Raw Material Preparation and Environmental Processing, University of Miskolc, Egyetemváros, 3515 Miskolc, Hungary

<sup>b</sup>associate professor, Institute of Mining and Geotechnical Engineering, University of Miskolc, Egyetemváros, 3515 Miskolc, Hungary

<sup>c</sup>research engineer, Dél-Konstrukt Ltd., Cserzy Mihály st. 35, 6724 Szeged, Hungary

## Abstract

Nowadays, electronic and electrical equipment for example smartphones, laptops, personal computers, car electronics, etc. represent one of the fastest growing waste (WEEE) stream caused by the accelerated technological development. These devices contain a lot of valuable elements: critical elements (rare earth elements, platinum group metals, In, Ga), precious metals (Ag, Au) and other metals (Cu, Ni, Sn) as well as plastics (polyamide, polyethylene, polypropylene, poly (methyl methacrylate)). The mass ratio of plastics can reach up to even 70% in devices, depending on many parameters, mainly the production year and the application type. Considering mechanical processing methods, sensor-based sorting plays a significant role in waste preparation. The different types of plastics can be separated from each other by applying Near-Infrared (NIR) separators. Present paper gives a literature overview in the field of mechanical processing methods related to WEEE, focusing on NIR separation.

**Keywords:** WEEE, processing, NIR, separation, recycling

## 1. Introduction

Processing of electrical waste is a huge problem in most European country. Due to the technological development every year more and more electrical waste have to treat. It is seen in Figure 1, that the volume of collected and treated WEEE in Hungary increase steadily, however the Crisis of 2008 stopped the growing for some year.

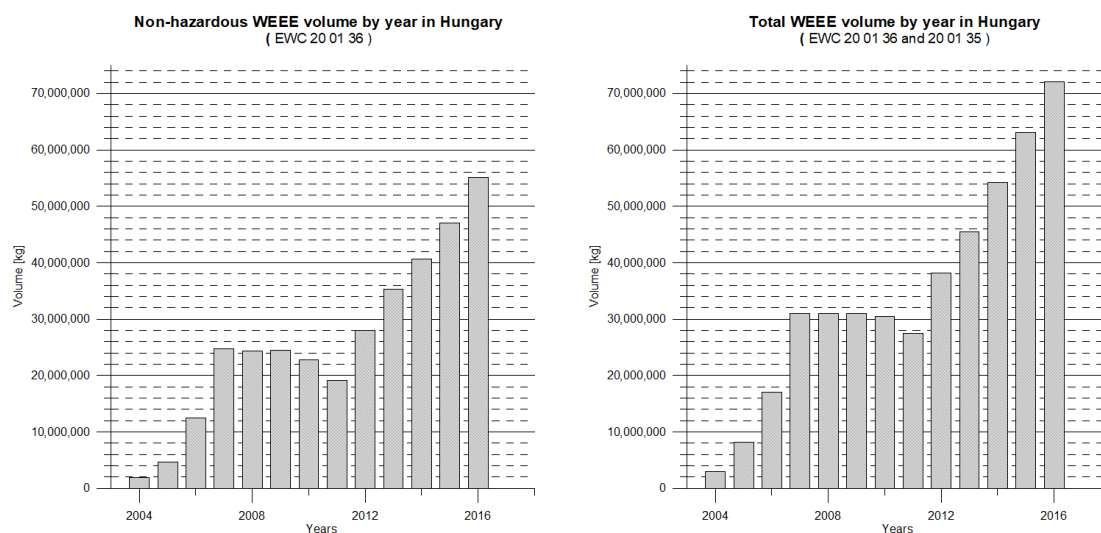


Fig. 1. Non-Hazardous and Total WEEE volume in Hungary (National Environmental Information System, 2018).

\* Corresponding author. Tel.: +36-46-565-111/18-08

E-mail address: gtbvir@uni-miskolc.hu



The commonly used method to process the electric waste is disassembling by workers than sell plastic and metal parts for recycling.

## 2. Typical mechanical preparation technology for WEEE

The flowsheet of typical mechanical preparation technology for WEEE can be seen in Figure 2 (Csőke, 2016). The first step of the mechanical processing is crushing. Shredders are often used as crushers in order to ensure the appropriate liberation by complex forces. The appropriate liberation is determined by the maximum particle size of crushing product. Table 1 summarizes recommended maximum particle size values for some typical WEEE.

Table 1. Recommended maximum particle size values for some typical WEEE related to appropriate liberation

Type of WEEE	Maximum particle size, $x_{\max}$ [mm]
Household small appliance	15..20
Telephone	5
Personal computer (PC)	2
Chip	1
Printed circuit board (PCB)	0.5

During mechanical preparation process the particle size becomes finer and finer after each crushing step. According to the mentioned above different machines can be applied to separate the valuable materials (Fe, plastics and non-ferrous metals) considering the particle size. After the first crushing step, belt magnetic separator is suggested for bigger particle sizes, while after the second crushing step drum magnetic separator can be used for smaller particle sizes. Non-ferrous metals can be separated by Eddy current ( $x > 3 \dots 4$  mm) or electrostatic separator ( $x < 3$  mm) depending on the particle size of feed material.

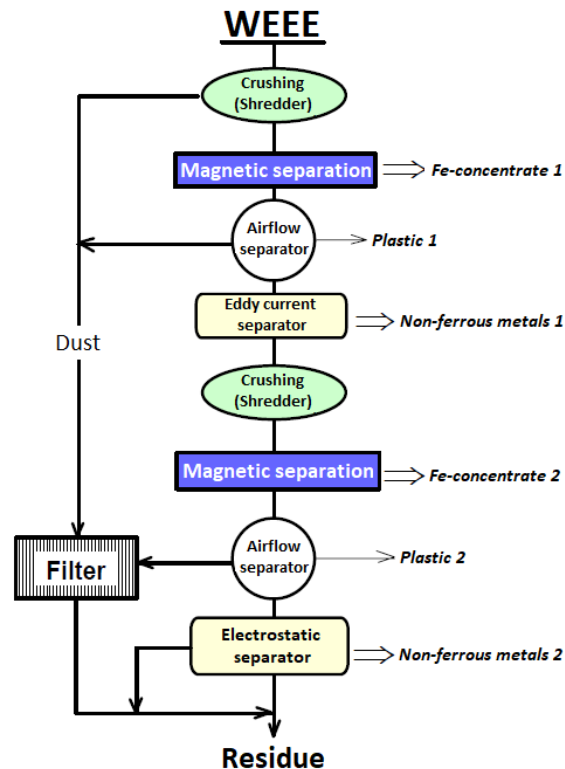


Fig. 2. The flowsheet of typical mechanical preparation technology for WEEE (Csőke, 2016).

## 3. NIR separation technique for WEEE

The samples are illuminated by a constant light source and either detect a camera reflecting from the sample. The analogue signal captured by the camera placed above the conveyor is proportional to the wavelength of the beam of light. The selection is provided with two air jet nozzles, so there are three products at the same time for the sorting device. In the arrangement shown in Figure 3.

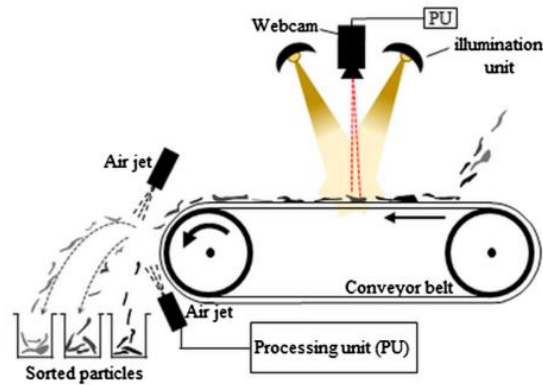


Fig. 3. NIR separator (Gundupalli et al., 2017)

#### 4. Alternative separation techniques for WEEE

##### 4.1. Sorting equipment with eddy current sensors

In this type of separator – like the eddy current separators – eddy current induced in the particles due to a transmitter coil, but this Lorentz force is weaker than the ordinary eddy current separators. In this case, when the transmitter coil induces the eddy current, the electromagnetic sensor (EMS) detects the electrical conductivity of the various non-magnetic metals. After identification, the particles spilling out by an air jet from the nozzles. (Figure 4).

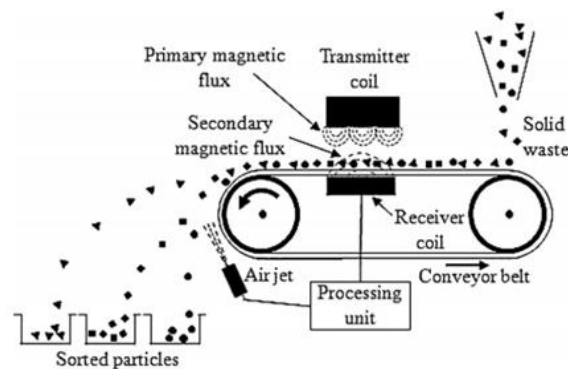


Fig. 4. EMS sensor-based separator (Gundupalli et al., 2017)

##### 4.2. Laser induced plasma spectroscopy

Laser-induced breakdown spectroscopy (LIBS) uses a high-energy laser beam. In 1990, the technology was developed at the Los Alamos National Laboratory, in collaboration with Metallgesellschaft, to identify metal waste. The LIBS system produces a large spectrometry of metal alloys, plastics and treated wood. Advanced atomic spectrometry technique based on optical emission monitoring of a microplasma generated by laser ablation. That is a very short-lived, time-varying temperature and composition source, it is necessary to synchronize with a laser at time with the precision of  $\mu\text{s}$  fraction to operate the high-resolution spectrometer that can capture the entire UV and / or visible spectral range simultaneously (Figure 5).

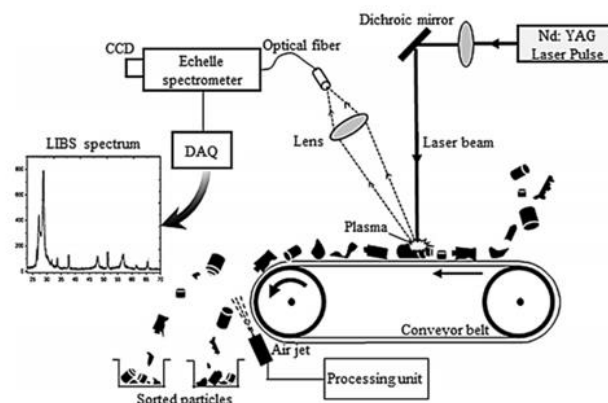


Fig. 5. The LIBS Separator (Gundupalli et al., 2017)

### 4.3. X-ray separators

Two versions of X-ray separators are known. Thanks to the X-ray transmission system, image processing takes place quickly, in a few milliseconds. During operation, a high-intensity X-ray passes through the material, absorbing some of its energy, while the rest of the weakened X-ray is a tape detector. The atomic density can be determined from the information (Figure 6).

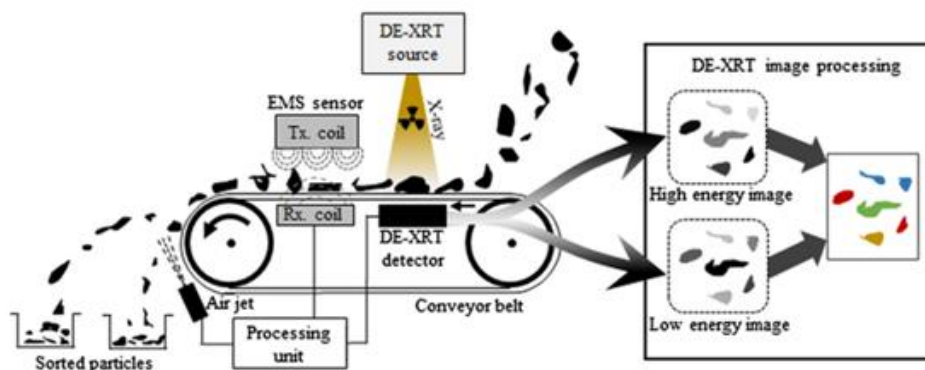


Fig. 6. XRT Sensory X-ray Separator (Gundupalli et al., 2017)

An X-ray fluorescence spectroscopy (XRF - X-ray fluorescence) ionizes the examined sample of electrons on a continuous spectrum X-ray. The kinetic energy of the leaving electron will be the difference between the photon and the electron binding energy.

### Acknowledgements

The described work/article was carried out as part of the „Sustainable Raw Material Management Thematic Network – RING 2017”, EFOP-3.6.2-16-2017-00010 project in the framework of the Széchenyi2020 Program. The realization of this project is supported by the European Union, co-financed by the European Social Fund.

### References

- Csőke, B., *Waste Management*, Lecture Notes, University of Miskolc, (2016).
- Gundupalli, S.P., Hait, S., Thakur, A., A review on automated sorting of source-separated municipal solid waste for recycling. *Waste Management*, Vol. 60, pp. 56–74, (2017).
- \*\*\*, National Environmental Information System, Ministry of Agriculture, (2018).

## Nitrite content in the samples collected from in land surface waters in Gradinari village

Petcov Andreea Adriana<sup>a\*</sup>, Camen Dorin<sup>a</sup>, Moatăr Mihaela<sup>a</sup>, Petolescu Cerasela<sup>a</sup>, Turc Alina<sup>a</sup>, Sasu Andreia<sup>a</sup>

<sup>a</sup>Banat's University of Agricultural Sciences and Veterinary Medicine „King Michael I of Romania” from Timișoara, Romania

---

### Abstract

Water is one of the three vital elements needed for humanity by air and food, but we often overlook its importance (Zăvoianu, 2005). Water pollution is a topical issue with an important impact on ecological balances (<http://www.mmediu.ro>).

Surface water comes from atmospheric precipitation, snow melting and springs, depending on the incline of the soil and the relief. ([www.arin.ro](http://www.arin.ro)) Normally, the water contains small amounts of nitrates. These result from mineralization of organic matter in water. (NIHWM).

The origin of nitrates can be highly mineralized soil and rich in nitrogen, soil pollution with organic residues. (this is also the most common way of water pollution with nitrites) (<http://www.scientia.ro>)

For the studies done in Gradinari village, Caras - Severin county, were collected water samples at a depth of 9, 10, 12 meters from the well. The harvesting was carried out both in winter and summer (October, December, February, May, July). For the values obtained from the analyzes carried out on the samples taken, the nitrite content in no case exceeded the maximum permitted limit of 0,50 mg/l.

*Keywords:* water, pollution, nitrite

---

### 1. Introduction

The assessment of the surface water quality consists in the measurement of the physico-chemical, biological and bacteriological parameters, on the control sections, establishing the way the standard norms are observed (Josan N, 2002). Surface water differs according to many characteristics: the flow and its variations (to the flowing), the temperature, the concentration and nature of the dissolved or suspended substances, the biological and microbiological content, etc., each mass of liquid water with its bedding and the living creatures being a distinct ecosystem (Alexa E., 2005). Surface waters have many common characters: unlike underground ones, they are typically less mineralized, richer in biological elements, more influenced by other factors (natural and anthropic), more easily polluting, less stable in features, but also have higher capabilities to auto maintain their quality. Comoraste village, has no centralized water supply system.

The water supply of the inhabitants is made from wells, the level of water from the fountains varies from 0.70 m to 14 m, depending on the area (Botoș and Lăzureanu, 2009).

Considering that Ciornovăț river is not a possible source of drinking water, and from deep drilling can not provide drinking water, the water being sandy clay (Luca and Tărașu, 2002).

Not any unpolluted human anthropic water is usable for human consumption, and there is no "standard" natural water to treat as natural pollutants, although the anthropocentric conception has made such a term relevant only for water use to man and not to the understanding of water as a whole (Cuc, 2006).

However, in almost all waters there is life that has adapted to those conditions. The same can not be said about waters with human-modified qualities (Vișan et al., 2000).

---

\* Corresponding author. Tel.: +4-0744218842.  
E-mail address: andreeazun@yahoo.com

## 2. Materials and methods

The sampling point studied and noted with Gradinari (Fig.1), is a private property fountain in the Caras - Severin county, located in close proximity (about 150 m) of a zootechnical farm. The working technique is based on legislation that measures the ability of substances to absorb or emit light energy at a characteristic wavelength. From a qualitative point of view, the positions of the absorption or emission lines and streams appearing in the electromagnetic spectrum indicate the presence of a certain substance. From a quantitative point of view, the intensity of the emission or absorption bands or tapes is measured for both standards and samples, then the concentration of the analytes.

An important fact to be mentioned and which underpinned the research at this location is that although there is a water supply network in the Gradinari, 70% of the locals use the water from their own fountains.

The water analyzes consisted in sampling groundwater samples from the fountain of Gradinari locality of Caras - Severin, at depths of 9 m, 10 m and 12 m.

The analyzes performed were those of the nitrite content and the steps taken to obtain the experimental results are as follows:

- Sampling
- Preparation of samples for analysis.
- The proper analysis.
- Calculation and expression of results.

For surface sources, water analysis is carried out by harvesting it 2 - 4 times a year during the most critical periods of pollution, namely at minimum winter and lowest summer temperatures (the highest temperatures) and maximum spring and / or autumn flows (after rain or snow melting). The tests used are SPECTROQUANT NITRIT 14776. (AquaMerck)

Conservation of water samples is another important aspect of the harvesting process, it is a concern to preserve samples for analysis because water analysis is of limited value if the samples have undergone physical, chemical or biological changes during transport or storage.

It is generally advisable to pass a very short time - up to 4 hours - between sampling and analysis of water samples. Preserved samples should be kept at 6 ° - 10 ° C. The water sample vials were transported in isothermal packaging to keep them from being hit.



Fig. 1. Sample collecting point at Gradinari location

## 3. Results and discussions

For the determination of nitrite content in surface waters, samples from the same water sources were collected at the indicated depths.

The content of nitrites in the surface waters analyzed in Gradinari village ranges from 0.43 mg/l to 0.48 mg/l.

As a result of the analyzes carried out there was no exceedance of the allowed nitrite level below this threshold 0,50 mg/l at Gradinari I, Gradinari II and Gradinari III; but the concentration of nitrite in water is quite high 0.48 mg/l Gradinari I in May month, to the depth of 9 m, respectively 0.48 mg /l Gradinari III in October month, to the depth of 12m, below the maximum admissible limit (Table 1 and Fig. 2)

Table 1. Nitrite content in the samples collected from in land surface waters in Gradinari village

Crt. No.	Village/ depth of harvesting	Month				
		October	December	February	May	July
		mg/l				
1	Grădinari I – 9 m	0.47	0.46	0.45	<b>0.48</b>	0.42
2	Grădinari II – 10 m	0.42	0.39	0.32	0.41	0.43
3	Grădinari III – 12 m	<b>0.48</b>	0.30	0.32	0.39	0.40

\*LMA 0.50 mg/l

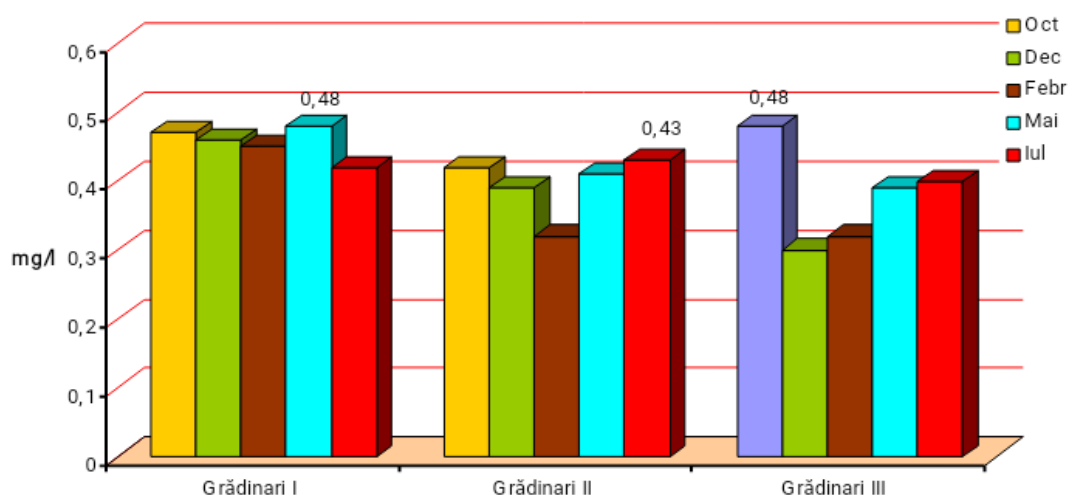


Fig. 2. Representation of nitrite content in the samples collected from inland surface waters in Gradinari village

Nitrite occurs in soils often only in low traces. Forms during nitrification from ammonia or ammonia but is immediately oxidized to nitrate. Microbial degradation processes are formed at different intermediate ammonium stages (ammonification). Water quality does not remain constant over time, but may vary due to many factors, either man-produced (human factors) or natural (which is obviously contributing to human action).

#### 4. Conclusions

Harmful are in fact nitrites that result from nitrates under certain conditions, where nitrates are reduced to nitrite generating secondary nitrate toxicity.

Chemical compounds of nitric oxide -  $\text{NO}_3$  - have a very high incidence in nature. They are present in the soil, in standing or flowing water, in the chemical composition of various plant or animal components, and even in meteoric water.

A cause of exceeding the maximum permitted nitrite limit would have been due to intensive farming through the use of significant amounts of nitrogen-based fertilizers over the years, as well as amendments from fertilizer plants. All of this would have contributed to the increase in nitrite content in surface waters.

As a general conclusion it can be stated that, as a result of the researches carried out for 5 months, it is that in the surface water from the analyzed fountain, it is not polluted with nitrites, being in accordance with the European requirements, it does not exceed the maximum admissible limit of 0.50 mg/l.

The use of the analyzed water drill at Gradinari collection point, Caras-Severin, is recommended to be monitored due to the presence of a content close to the maximum admissible limit.

Pollution with nitrites and not only surface waters occurs through the influence of several factors among which we mention a part of them:

- the passage of water through areas of soluble rock - natural sodium chloride, sulphates, sulphites, carbonates, bicarbonates, which makes the shallow surface or groundwater load with higher or lower amounts of such salts, in relation to the concentration of rocks in such salts and the distance traveled by the water in the leaching process
- the passage of surface water through areas with soil erosion processes - this process causes the water, with a meteoric initial source, to pass through the impurities and various materials that enter into suspension in water and which causes the content of these waters to increase in the nitrite compounds.
- the development of hydrophilic and aquatic vegetation - this type of vegetation can create pollution phenomena especially in stagnant or slow-flowing waters. The intensity of water contamination processes is strongly dependent on the length of the vegetation period and on the rhythm of the metabolic processes of the plants.

## References

- Alexa E., *Contaminanți în produsele vegetale*, Ed. Eurobit, Timișoara, 2005.
- Botos, A., Lazureanu, A., Contamination with nitrates and nitrites of the surface waters in Gradinari locality, Caras-Severin County, *Lucrări Științifice Facultatea de Horticultură și Silvicultură*, Vol. 13, Editura Agroprint, pp.159 – 162, (2009).
- Cuc, L., *Ecologia apei*, Editura Eurobit, Timișoara, (2006).
- Josan, N., *Sisteme globale de mediu*, Ed. Universitară, Oradea, (2002).
- Luca, M., Tarau, D., *Panoptic al comunelor băcănești din perspectiva pedologică*, Editura Marineasa, Timișoara, (2002).
- USGS – U.S. Geological Survey, *The water cycle*, National Institute of Hydrology and Water Management (NIHWM).
- Zăvoianu, I., *Hidrologie, ediția a II – a*, Editura Fundației României de Măine, București, (2005).
- Vișan, S., Anghelescu, A., Alpopi, C., *Mediul înconjurător, poluare și protecție*, Ed. Economică, București, (2000)
- \*\*\* <http://www.mmediu.ro>
- \*\*\* [www.arin.ro](http://www.arin.ro)
- \*\*\* <http://www.scientia.ro>



## Challenges and opportunities associated with waste recycling development in Romania

Lucian-Ionel Cioca <sup>a</sup>, Larisa Ivascu <sup>b\*</sup>, Szilard Szekely <sup>a</sup>

<sup>a</sup>Lucian Blaga University of Sibiu, Department of Industrial Engineering and Management, Faculty of Engineering, Bd. Victoriei No. 10, 550024 Sibiu, Romania;

<sup>b</sup>Politehnica University of Timisoara, Departament of Management, Faculty of Management in Production and Transportation, Victoria Square No. 2, Timisoara 300006, Romania

---

### Abstract

European Union (EU) policies are regularly targeting a number of actions on reducing municipal waste and increasing its recycling rate. From this perspective, the situation in Romania is not a favorable one and requires measures for improvement. The recycling rate of Romania is well below the EU average. For Romania, in 2017, the recycling rate was 14.5%, and at for the EU it was 46.9%. This paper aims to assess Romania's capacity to increase its recycling rate. It also presents the EU situation. At the end of the evaluation, a conceptual framework of challenges and opportunities is proposed in order to reach the EU objective of recycling policies. Finally, the findings of this study are advancing the specialized literature by the radiography made in this field of waste management. At the end of the paper, the main conclusions of the study and future research directions are presented.

*Keywords:* waste management; strategy; recycling; reuse; policy.

---

### 1. Introduction

The UN's 2030 Agenda for Sustainable Development offers a new global framework that contributes to poverty reduction, combating inequalities and combating climate change. Sustainable development also takes into account occupational hazards (Babut and Moraru, 2018). The agenda includes 17 objectives and their related 169 targets. Since 1990, the EU has introduced policies and targets on waste. These include a series of strategies that pursue the goals of sustainable development. Since 2005, the Thematic Strategy on the Prevention and Recycling of Waste (EC, 2017) and framework legislation such as the Waste Framework Directive (EC, 2017) sets the target for 50% of municipal waste to be prepared for reuse and recycled in EU member states. In 2015, the European Commission publishes the document "Closing the Loop - An EU action plan for the circular economy (EC, 2017) (or Circular Economy Package)". This document sets out a number of new objectives. A first objective is to reach the recycling rate of 55% by 2025. Municipal waste includes household waste and other refuse, which, by nature or composition, are similar to household waste (Ministry of Environment, GD no 349/2005, 2017).

Waste is a major problem in Romania. The country's waste generation rate is on the rise. This increase is due to the degree of urbanization, industrialization and population behavior. Faulty waste management can cause adverse effects on the environment, risk to public health, excessive environmental pollution and other economic and social problems. In EU, waste management shows an improved situation, superior to the situation in Romania. There are a number of regulations and norms that guide EU member states in enhancing waste management (NIS, 2018).

The Environment Committee within the European Parliament approved this year a set of new regulations which oblige EU member states to increase the recycling percentage and encourage producers and consumers to reuse valuable materials imbedded in wastes. This new set of rules establish legally mandatory targets for waste recycling and the reduction of land filling that have fixed deadlines (Antonopoulos et al., 2014).

---

\* Corresponding author. E-mail address: larisa.ivascu@upt.ro

The paper presents an overview of the current state of waste management and recycling management. Starting from the existing situation in Romania and in line with the EU objectives and measures, the paper identifies the challenges and opportunities associated with waste recycling development in Romania. The results of this research can help the competent authorities responsible for urban solid waste management, contracting companies and researchers to develop new opportunities and strategies to improve the situation.

## 2. Waste management: system quality and new EU rules

In Europe, the amount of municipal waste that is recycled has steadily increased as a result of investment in the collection, proper handling of financial incentives to move away from waste disposal and the banning of landfills in the member states. The performance of EU member states with regard to municipal waste recycling varies, due to multiple factors (economic power, technological innovation capacity, population density and so on). The Circular Economy Package (EC, 2017) contains a number of objectives and measures to be achieved. Among these are:

- Increase the recycling and reuse rate to 65% by 2030 for municipal waste;
- Increase recycling and reuse rate to 75% by 2030 for packaging waste;
- Reduction of landfills up to 10% of municipal waste by 2030;
- Prohibiting the storage of separately collected waste;
- Promoting and implementing economic instruments to deter storage at the level of each country;
- Develop simplified definitions and harmonized calculation methods for recycling rates for all EU member countries;
- Promoting the principles of the circular economy by developing concrete measures to promote the re-use and stimulation of industrial symbiosis - transforming the by-product of an industry into a raw material;
- Launching incentives for producers. Manufacturers should market organic products and support recovery and recycling systems (e.g. packaging, batteries, electrical and electronic equipment and vehicles).

In EU, the targets set by "Closing the loop — An EU action plan for the circular economy" on increasing the recycling rate are being pursued. "Waste recycling is defined as any recovery operation by which the waste is reprocessed in products, materials or substances, either for original purposes or for other purposes. This includes reprocessing of organic materials (e.g. by composting or digestion), but does not include the recovery and recycling of energy in materials to be used as fuels or for filling operations" (EC, 2017).

The quantity of waste generated in the EU in the period 2012-2017 is presented in Figure 1. The amount of waste is increasing, hence the objectives.

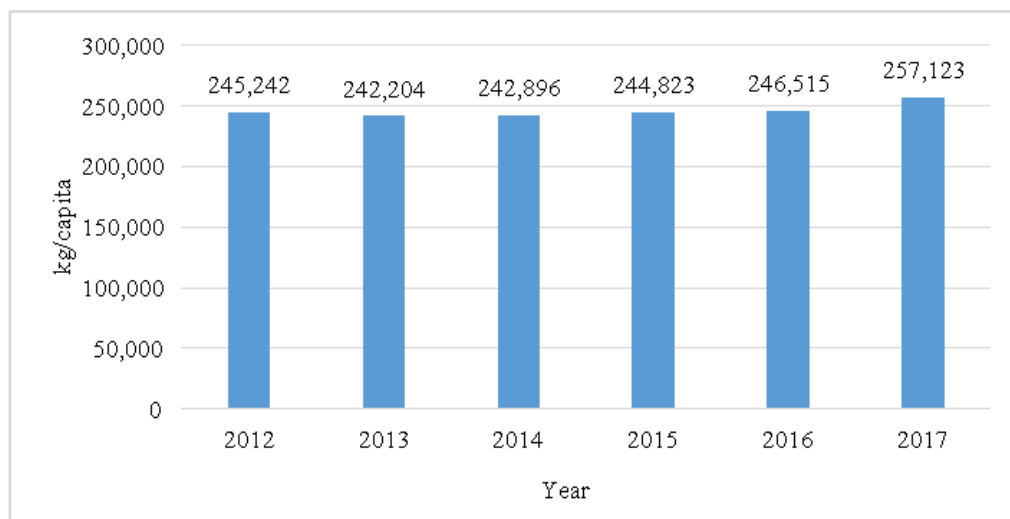


Fig. 1. The amount of waste generated per capita in EU (kilogram/capita) (EC, 2017)

Depending on the method applied to municipal waste, the situation in the EU is presented in Figure 2. It can be noticed that the overall rate of recycling (material recycling, composting and digestion) is increasing, in 2012 it was 41.5%, and in 2017 it was 46.9%. This improvement in recycling rate is a combination of a reduction in the amount of municipal waste generated and the increase in the total recycled, composting and digestive amount (Karak et al., 2014). This growth is considered a success for environmental policy in Europe from 1990 to the present.

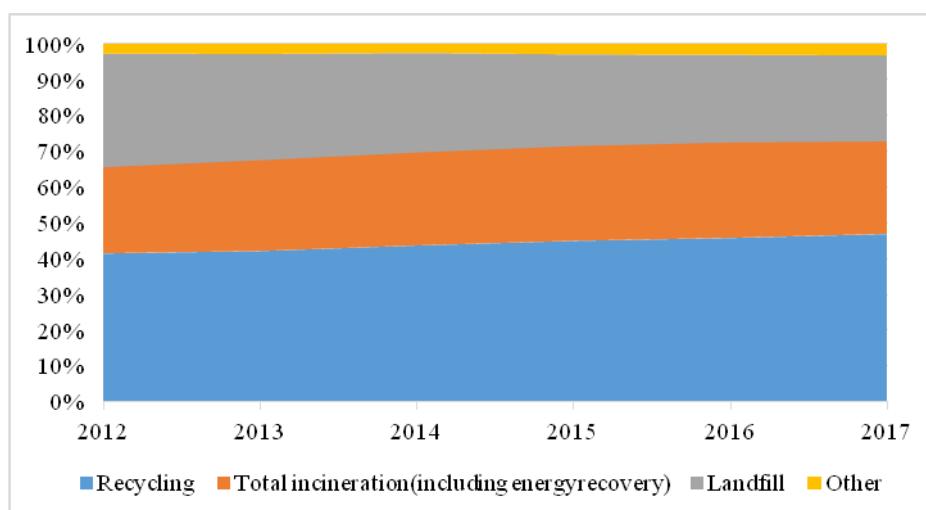


Fig. 2. Share of treatment methods of municipal waste (EC, 2017)

Municipal waste is covered by EU rules and regulations to be reduced (Pires et. al., 2011). Recycling rates for 2012-2017 are shown in Table 1. It can be seen that the recycling rate has increased annually. This recycling rate is expected to increase annually so that in 2025 it will reach 60%. From the perspective of the municipal waste recycling rate, for EU the situation of the rate increase targets is presented in Table 2. It can be seen that the recycling rate is expected to increase by following the objectives of sustainable development (17 Global Goals for Sustainable Development).

Table 1. Municipal waste recycling rate in the period 2012-2017 in the EU

Year	2012	2013	2014	2015	2016	2017
Recycling rate (%)	41.5	42.5	43.6	45	45.8	46.9

Table 2. Recycling targets for municipal waste

Year	By 2025	By 2030	By 2035
Percentage of recycling (%)	60	65	70

### 2.1. The situation in Romania

In Romania, the competent decision-making and controlling authority in the field of waste management is the Ministry of Environment. Municipal waste includes household waste, industrial and institutional waste, commercial waste, street waste, park and garden waste, waste from urban water purification and construction and demolition waste (Rada et al., 2017). Waste management in Romania includes the following municipal waste management infrastructure (Ministry of Environment, 2017): 51 transfer stations; 101 sorting facilities with a total capacity of approx. 2,431,420 tons / year; 22 composting plants with a total capacity of approx. 180,000 tons / year; 3 mecano-biological treatment plants with a total capacity of 117,000 tons / year; 35 warehouses with a total built-up capacity of 48.1 million tons and 15 non-compliant warehouses with assisted activity in 2016 or 2017. Out of the 101 sorting facilities only 93 are sorting facilities, the remaining 8 having authorized sorting waste from the pile. The 93 screening plants have the following sorting capacity, Table 3:

Table 3. Capacity of sorting facilities in Romania

Capacity of sorting installations	Capacity of installations
93 are sorting equipment installations in Romania	34 plants have a total capacity of about 200,000 tons / year and sort recyclable waste collected separately;
	34 plants have a total capacity of about 700,000 tons / year and sort municipal waste collected in the mix;
	25 plants have a total capacity of about 1,381,420 tons / year and sort separately collected recyclable waste and municipal waste collected in the mix.

More than 45 sorting stations are currently being implemented and their number will be close to 150 nationally. Most are funded through environmental programs. The composting stations are continually developing. New composting facilities are being built and their number is close to 45. New mechanical-biological treatment plants are being developed including an additional 14 (MM, 2018). The total capacity of mechanical and biological treatment facilities is 1,459,000 tons / year. The amount of waste generated per capita is shown in Figure 3. It is noticed that during the period 2012-2015, the amount of waste is decreasing, followed by an increase during the period 2016-2017. This evolution of waste is due to the industrialization and increase of the socio-economic level.

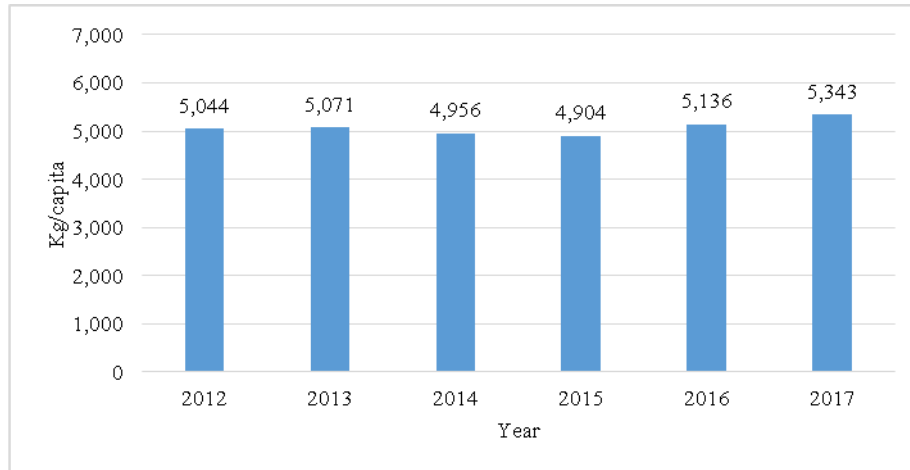


Fig. 3. The amount of waste generated per capita in Romania (kilogram/capita) (NIS, 2017)

In Romania, the recycling rate of municipal waste is well below the average recorded at the EU level. This rate is shown in Table 4. It is noticed that starting with 2012, the recycling rate is on the rise. This growth is slow, succeeding in 2017 to reach the level of 14.5%

Table 4. Recycling rate of municipal waste in the period 2012-2017 in Romania (NIS, 2017)

Year	2012	2013	2014	2015	2016	2017
Recycling rate (%)	12.8	13.2	13.1	13.2	13.3	14.5

Effective municipal waste management at national level is achieved through collection operators and treatment operators.

### 3. Strategic framework for municipal waste management in Romania

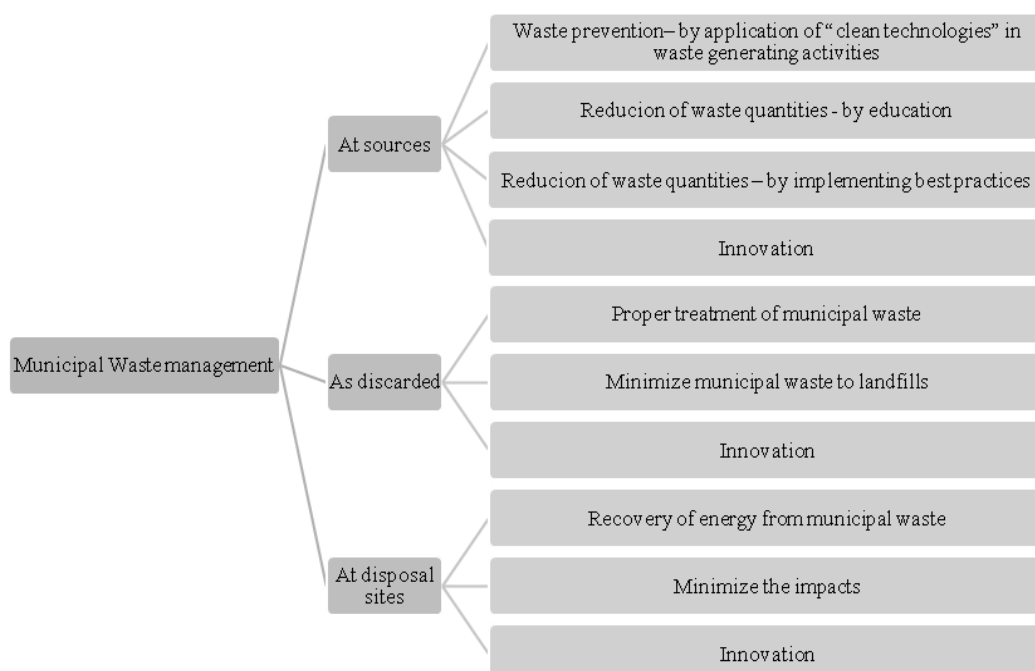


Fig. 4. Strategic framework proposed to improve the current situation in Romania

The situation in Romania needs to be improved to meet the EU's waste management levels. From this perspective, proposing a strategic framework and activities is important. Figure 4 shows a strategic framework taking into account the three directions: at sources, as discarded, and at disposal sites.

The actions to be implemented to increase the quality of the waste management system are related to the existing infrastructure, the human resource involved in waste management activities, and the population. The general strategic objectives for waste management are (Ministry of Environment, 2018):

- Legislative policies and applicable norms - streamlining their application, integrating legislative requirements with economic environmental norms, harmonizing national norms with European norms. Harmonizing and developing national requirements in harmony with European ones.
- Human Resources - Professional training of human resources in accordance with national and European requirements.
- Enhance financial management - reduce costs and apply the "polluter pays"
- Promoting and informing people and agents about the current state of waste management and EU rules and objectives.
- Integrated system - implementation of integrated IT systems for real-time, complete and relevant situations. These situations can be used in future decisions.
- Preventing waste generation - awareness and training of the population on reducing the amount of waste generated.
- Waste recovery - exploring technological and economic opportunities for waste recovery.
- Efficiency of waste collection and transport - the use of innovative and sustainable systems.
- Waste treatment - using waste treatment to ensure rational environmental management.
- Storage - reducing the amount of waste stored to protect the health of the population and the environment.
- Research and development - encouraging and supporting waste management applications to identify the most innovative techniques and methods that are applicable at national level.

#### 4. Summary of findings

Assessing the research, we can conclude on the following aspects regarding Romania's capacity to comply with EU waste recycling requirements:

- Investing in innovation to increase the technology rate of this sector;
- EU objectives and rules follow the 17 sustainable development objectives and related measures;
- EU objectives and norms are moving towards increasing recycling rates;
- The recycling rate in Romania is 14.5% below the EU level of 46.9%;
- Selective collection infrastructure complies with European provisions, but needs to be improved;
- The selection infrastructure must be expanded so that the recycling rate can increase;
- The amount of waste / capita may grow annually as a result of industrialization and socio-economic stability;
- Efforts to reduce environmental pollution should be sustained and implemented at the level of each EU country.

#### Conclusions

At national level, waste management activities are carried out on the basis of the following principles: the principle of primary resource protection, the precautionary principle related to the use of 'best available techniques not entailing excessive costs – BATNEEC', the prevention of generation, the 'polluter pays' principle correlated with the principle of producer responsibility and user responsibility, the principle of substitution, the principle of proximity correlated with the principle of autonomy and the principle of subsidiarity. Romania's recycling level is well below the EU level, so the current rules and provisions should be revised. The degree of innovation can be improved, and information and education of the population could be solutions for increasing the recycling rate.

#### References

- Antonopoulos, I.S., Perkoulidis, G., Logothetis, D. Ranking municipal solid waste treatment alternatives considering sustainability criteria using the analytical hierarchical process tool. *Resour Conserv Recy*, Vol. 86, 149–159, (2014). doi.org/10.1016/j.resconrec.2014.03.002
- Băbuț, G.B., Moraru, R.I., Occupational risk assessment: imperatives for process improvement, *Quality - Access to Success*, vol. 19, No. 166, 133-144, (2018).
- Circular Economy Package (EC, 2015), *Circular economy package - Four legislative proposals on waste*, available at <http://www.europarl.europa.eu/EPRS/EPRS-Briefing-573936-Circular-economy-package-FINAL.pdf> (accessed on 20 august 2018).
- European Commission (EC), *Annual Indicator Report Series (AIRS) — In support to the monitoring of the 7th Environment Action Programme - Recycling of municipal waste*, EC, (2017).
- Karak T., Bhagat, R.M., Bhattacharyya P., Municipal Solid Waste Generation, Composition, and Management: the world scenario, *Crit Rev Environ Sci Technol*, Vol. 42, 1509-1630, (2014). <http://dx.doi.org/10.1080/10643389.2011.569.871>.

- Ministerul Mediului (MM), Planul Național de Gestionare a Deșeurilor - versiunea 5, available at [http://www.mmediu.ro/app/webroot/uploads/files/PNGD\\_vers5.pdf](http://www.mmediu.ro/app/webroot/uploads/files/PNGD_vers5.pdf) (accessed on 10 July 2018).
- National Institute of Statistics (NIS), Statistical data and metadata DB, available at <http://www.insse.ro/cms/en/content/sustainable-development-indicators> (accessed on 10 July 2018).
- Pires, A.; Chang, N.B.; Martinho G., Reliability-based life cycle assessment for future solid waste management alternatives in Portugal. *Int J Life Cycle Assess*, Vol. 16, No. 4, 316–37, (2011). doi: 10.1007/s11367-011-0269-7
- Rada E. C., Cioca L. I., Optimizing the Methodology of Characterization of Municipal Solid Waste in EU under a Circular Economy Perspective, *Energy Procedia*, Vol. 119, 72-85, (2017). doi: <https://doi.org/10.1016/j.egypro.2017.07.050>.
- Wang, Z., Ren, J., Evan Goodsite, M., Xu, G., Waste-to-energy, municipal solid waste treatment, and best available technology: Comprehensive evaluation by an interval-valued fuzzy multi-criteria decision making method, *Journal of Cleaner Production*, Vol. 172, 887-899, (2018). doi.org/10.1016/j.jclepro.2017.10.184

## Improve Air Quality Management by Monitoring and Assessing Heavy Metal Emissions. Case Study: Hunedoara County, Romania

Ileana-Sorina Rakosa<sup>\*</sup>, Sorinel Căpușneanu<sup>b</sup>, Dana-Maria (Oprea) Constantin<sup>c</sup>,  
Dan Ioan Topor<sup>d</sup>, Elena Bogan<sup>d</sup>

<sup>a</sup>University of Petroșani, University street, no. 20, Petroșani, 332006, Romania

<sup>b</sup>Dimitrie Cantemir Christian University, Bucharest

<sup>c</sup>University of Bucharest

<sup>d</sup>1 Decembrie 1918 University, Alba-Iulia

---

### Abstract

In the current context of global warming and increased frequency and intensity of severe weather episodes, acute need for sustainable development of the socio-economic environment involving all decision makers is needed. The companies that constitute the pyramid base of the economy must implement policies related to planning, control, assurance and improvement of quality. Air quality is part of total quality management. Monitoring and assessing pollutant emissions are the essential steps for continuously air quality improvement. The purpose of this paper is to analyse emissions of heavy metals (lead, cadmium and mercury) for the period 2003-2016 from the Hunedoara County territory in relation to causes that accentuate or diminish their daily, monthly and annual concentration values. The analysis was based on data provided by the Hunedoara Environmental Protection Agency (APM HD) and the European Environment Agency (EEA). The paper ends with the authors' conclusions based on the monitoring and assessing of heavy metal emissions as part of air quality management.

**Keywords:** Total Quality Management, emissions, heavy metals, atmosphere, Hunedoara County

---

### 1. Introduction

The territory of Hunedoara County is situated in the western part of Romania, being a diverse and harmonious geographic entity, being crossed by the Mureș River and its tributaries in the middle, having the southern upper Jiu River, and the north - the upper basin of Crisul Alb making the link between the western counties of Caraș-Severin, Timiș, Arad and Transylvania in the center of the country (Alba, Sibiu), as well as the counties in the south of the country (Gorj and Vâlcea). The administrative-territorial unit of Hunedoara County comprises 7 municipalities, 7 towns, 55 communes and 457 villages with a population of approximately 460,000 inhabitants.

The problems of environmental quality control have been set after mankind has undergone a brief evolution (on a geological scale) has multiplied (often at small intervals, the population has doubled), occupied in one form or another the whole surface of the planet, profoundly, affected or transformed the natural ecosystems and caused an unknown scare until then: pollution (Căpușneanu et.al., 2015). Industrial pollution addresses the problem of pollution from the workplace to the environmental consequences of the entire earth globe. Industrial pollution of the environment is generally spread by air and water. For the air pollution, both the electricity industry, the gases exhausted by the thermal power plants in the atmosphere, as well as the industrial branches, such as: *the chemical industry and building materials, and especially the ferrous and non-ferrous metallurgy, are to blame*. The most important step in increasing the quality of the environment is the elimination of products that use excess energy and natural products or contain dangerous substances or releases harmful emissions (Constantinescu (Oprea) et. al., 2013).

Thus, there is a need to have a system for monitoring the quality of the environment irrespective of the scale to which it refers or the number of components it encompasses in order to provide an objective image as close as possible to the reality of the environment for adopting correct pollution control and restoration. Being an activity that underpins

---

<sup>\*</sup> Corresponding author: tel: 0721 277 820  
E-mail address: nihilsinedeo\_68@yahoo.com



environmental policies and strategies, monitoring environmental quality requires an organization that takes into account both the complexity of the environment as a global system and the institutional structures that are responsible for it.

Data related to the state and the quality of the environment can be provided by country of different types of organizations, but above all by the National Environmental Protection Agency. The issue of air quality is a major concern for many European citizens and the institutions of the European Union.

## 2. Potential sources of air pollution in Hunedoara County

In Hunedoara County, the potential sources of air pollution are primarily the units for the production of electric and thermal energy, and in a second plan the steel plants, the units for the production of the building materials and the transports etc. The heavy metals emissions in Hunedoara County, according to the inventory of the agency, consist of mercury, cadmium, arsenic, chromium, copper, nickel, selenium, zinc and lead, and attention was paid to mercury, cadmium and lead. In the region, air quality is influenced by the technological processes of the mining industry and the former Hunedoara Steel Plant, currently S.C. ArcelorMittal S.A. Hunedoara, a company that produces tile for pipes, heavy, medium and light profiles, concrete steel, wire and special profiles for mining (<http://www.arcelormittalhunedoara.ro>). The main sources of pollution in Hunedoara County are presented in table 1.

Table 1. Major air pollution sources in Hunedoara County

Crt No	Source of pollution	Activity	The resulting atmospheric pollutants
1	S.C. Termoelectrica S.A. - S.E. Paroşeni S.C. Electrocentrale S.A. Deva S.C. Acvacalor S.A. Brad	Combustion plant with a rated output exceeding 20 MW	SO <sub>2</sub> , NO <sub>x</sub> , powder, CO <sub>2</sub> , CO
2	S.C. ArcelorMittal S.A. Hunedoara	Installations for the production of steels for continuous casting with a capacity of over 2.5 t / h	SO <sub>2</sub> , NO <sub>x</sub> , powder, CO <sub>2</sub> , CO
3	S.C. Carpatcement Holding S.A. Sucursala Deva	Installation for the production of cement clinker in rotary kilns with a production capacity exceeding 500 t / day	SO <sub>2</sub> , NO <sub>x</sub> , powder, CO
4	S.C. ArcelorMittal S.A. Hunedoara* * The installation for the production of lime and dolomite was closed on 27.10.2007	Installation for the production of lime and dolomite in rotary kilns with a production capacity exceeding 50 t / day	SO <sub>2</sub> , NO <sub>x</sub> , powder
5	S.C. Carmeuse Holding S.R.L. – Point of work in Chişcădaga	Installation for the production of lime with a capacity of over 50 t / day	powder, CO, CO <sub>2</sub>
6	S.C. Refraceram S.R.L. Baru	Installation for the production of bricks, refractory bricks with a capacity exceeding 4 m <sup>3</sup> and a density of more than 300 kg/m <sup>3</sup>	powder, CO, CO <sub>2</sub>
7		Traffic	SO <sub>2</sub> , NO <sub>x</sub> , CO <sub>2</sub> , CO

Source: own projection

Table 2 shows the major sources of air pollution, units under IPPC legislation, as well as greenhouse gases and pollutants emitted in the atmosphere, specific to them.

In Hunedoara County, industrial activities that have a significant impact on air quality are specific to some economic branches with tradition in the area: mining, iron and power generation (thermal and electrical) (<http://www.anpm.ro>). Mining activities for construction and the cement industry were exploited in quarries located in mining perimeters, on the basis of licenses and exploitation permits. The impact of mining mass activities is manifested by borehole work, sorting activities in sorting facilities, and dumping of tailings on heaps located outside the perimeter with reserves. The steel industry at the level of Hunedoara County was represented during the period 2003 - 2016 by the activities carried out within SC ArceloMittal Hunedoara SA.

The energy industry is represented by S.C. Energy Complex Hunedoara S.A. consisting of: The Mintia Workstation and the Paros Electric Power Plant, resulting in powder (fly ash) having local effects on the environment, through SO<sub>2</sub> and NO<sub>x</sub> emissions that contribute to the formation of “acid rain” with regional action and emissions CO<sub>2</sub> that contributes to the “greenhouse effect” increase. Emissions of CO, CO<sub>2</sub>, N<sub>2</sub>O, NO<sub>x</sub> affect the ozone layer.

The pollution of the atmosphere with suspended particles has many sources: first industrial processes, the most important quantity coming from metallurgy and steel, followed by solid fuels, cement factories, road transport, dumps and tailings (Law no. 278/2013). Characteristic for Hunedoara County are mainly tailings dumps and tailings ponds, whose particles are driven by wind over distances of tens of kilometres.

Transport is another factor contributing to air pollution with combustion products: *soot, carbon dioxide, hydrocarbons, lead*.

In order to create an integrative picture of the current environmental conditions, we will present the values of the main indicators related to a month with a high degree of pollution (i.e. August) and the average annual values. These values are compared with the limit values and the alert threshold according to the criteria of Law 104/2011 on ambient air quality (Table 2).

Table 2. The limits for the protection of human health provided by Law no. 104/2011 on ambient air quality

Pollutant	Criterion	Mediation period	Value	Measure Unit	Number of allowed annual exceedances (if any)
Suspended particles, $M_{10}$	Limit value	one day	50	$\mu\text{g}/\text{m}^3$	35
	Limit value	calendar year	40	$\mu\text{g}/\text{m}^3$	It's not necessary
Plumb Lead, Pb	Limit value	calendar year	0.5	$\mu\text{g}/\text{m}^3$	It's not necessary
Cadmium, Cd	Limit value	calendar year	5	$\text{ng}/\text{mc}$	It's not necessary
Mercury, Hg	Limit value	one day	50	$\text{mg}/\text{m}^3$	It's not necessary

Source: own projection

The Hunedoara Environmental Protection Agency is responsible for the annual inventory of emissions of air pollutants - emissions from both fixed sources such as energy burning and transformation industries, non-industrial combustion plants, burning in the processing industry, production processes, extraction and the distribution of fossil fuels and other products, waste treatment and disposal, agriculture, forestry, etc., as well as from mobile sources such as road transport, other mobile sources and machinery. Thus, in Hunedoara County, the Hunedoara Environmental Protection Agency operates five automatic air quality monitoring stations included in the National Air Quality Monitoring Network. They are located in Deva, Hunedoara, Călan, Vulcan.

Consequently, the urban station monitors the indicators:  $\text{NO}_x/\text{NO}_2$ ,  $\text{SO}_2$ , CO,  $\text{O}_3$ , VOC, PM10, Pb, and the industrial base stations monitor the  $\text{NO}_x/\text{NO}_2$ ,  $\text{SO}_2$ , CO,  $\text{O}_3$ , PM10, Pb indicators. The values resulting from the measurements corresponded to the tolerance limits established by the Law no. 104/2011

Heavy metals (mercury, lead, cadmium, etc.) are compounds that cannot be degraded naturally with a long retention time in the environment and are dangerous in the long run because they can accumulate in the food chain. These can cause muscular, nerve, digestive disorders, general apathy.

In Hunedoara County, the total area affected by industrial activities is over 10,000 ha. These branches of activity generate waste requiring final disposal and municipal waste disposal is carried out on sites that do not currently meet the environmental protection requirements.

### 3. The main traits of pollutants - heavy metals: cadmium, lead, and mercury (Cd, Pb, Hg)

There are 35 metals that are present in the workplace as well as in dwellings. Of the 35 metals, 23 metals are considered heavy, such as antimony, arsenic, bismuth, cadmium, cerium, chromium, cobalt, copper, gallium, gold, iron, platinum, silver, tellurium, thallium, tin, uranium, vanadium and zinc. The study has focused on three elements, namely cadmium, mercury and lead.

The main features of **cadmium**: in nature is found as combinations (CdS) in zinc ores; is highly toxic; they are used in alloys to increase the resistance of metals to corrosion agents, especially seawater; the most important source of cadmium contamination is industry, notably the non-ferrous metals industry and the combustion of fuels; is a strong enzyme inhibitor, especially with sulphuric enzymes.

Main features of **mercury (Hg)**: is one of the metals known since antiquity, being known as silver; the classical method for the preparation of mercury consists in roasting the cinnabar in the oven at 600-700°C, in the presence of air when the metal  $\text{SO}_2$  results (since the resultant mercury oxide is thermally unstable):



followed by cooling the mercury vapour in water-cooled sandstone condensers.

Sometimes, especially in the case of small-scale mining, the cinnabar is heated in the oven at 600-700°C, either with lime:



either with iron crunch:



is used in some electrolysis cells as a mercury cathode, in the extraction of gold and silver in various precision instruments and apparatus such as: thermometers, barometers, manometers, densitometers, high vacuum pumps, etc., in

the preparation of medicinal ointments, preparation of mercury fulminate, cinnabar, in AC rectifiers, ultraviolet lamps, amalgam preparation; in pure form, but also in compounds it is very toxic, and ingestion or inhalation can ultimately lead to respiratory arrest and death.

Main features of **lead (Pb)**: it has toxic effects; known and used since ancient times, lead, has constituted and is a major environmental pollutant; its accumulation in large quantities in soil as a result of pollution results in passive absorption in plants; is toxic to the brain, kidney, reproductive system and cardiovascular system; exposure to lead causes disturbances of the intellectual function, which is especially dangerous for children.

Pollution of the atmosphere with suspended particles has many sources: first industrial processes, the most important quantity coming from metallurgy and steel, followed by solid fuels, cement factories, road transport, dumps and tailings. Characteristic of Hunedoara County are mainly tailings dumps and tailings ponds, whose particles are driven by wind over distances of tens of kilometres.

#### 4. Results based on analysis of environmental quality pollution factors with Cd, Hg and Pb

The contribution of energy activity sectors to heavy metal emissions in Hunedoara County for the period 2003 - 2016 is summarized in figure no. 1.

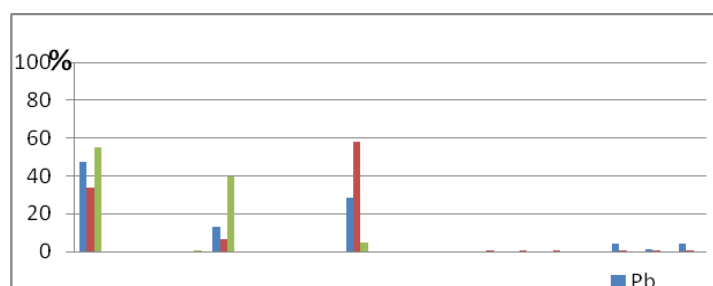


Fig. 1. Contributions of energy activity sectors to heavy metal emissions in Hunedoara County (Source: environmental reports 2003-2016, APM Hunedoara)

From the distribution of heavy metals emissions by sectors of activity it can be noticed that: the largest share of lead emissions comes from the production of electricity and heat (47.29%) and from residential heating (28.53%); the largest share of cadmium emissions comes from residential heating (57.85%), followed by the production of electricity and heat (33.55%); the largest share of mercury emissions comes from the production of electric and thermal energy (55.05%) and from combustion in industry (39.54%).

The contribution of the activity sectors to heavy metal emissions (Pb, Cd and Hg) in Hunedoara County between 2003 and 2016 is summarized in Figure 2.

From the data shown, the highest share of Pb, Cd and Hg comes from the energy sector and the industry sector.

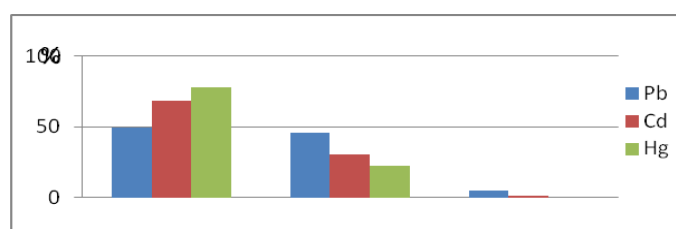


Fig. 2. Contribution of the activity sectors to heavy metal emissions in Hunedoara County (Source: environmental reports 2003-2016, APM Hunedoara)

The contribution of industry subsectors to metal emissions, at the level of Hunedoara County in 2016, is shown in Figure 3:

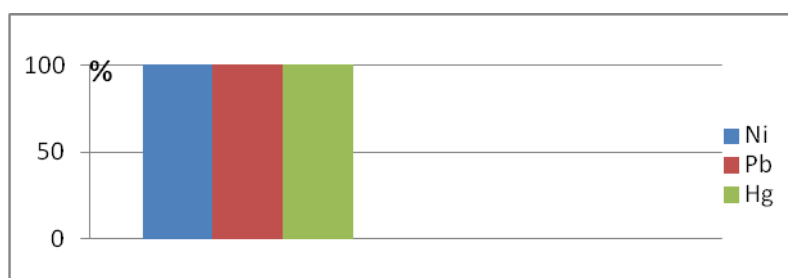


Fig. 3. Contribution of industry sectors to heavy metal emissions in Hunedoara County (Source: environmental reports 2003-2016, APM Hunedoara)

The share of heavy metal emissions in the industry subsectors, related to Hunedoara County, comes from the production of cast iron and steel. The contribution of transport vehicle types to heavy metal emissions (Pb, Cd), at the Hunedoara County level in the period 2003 - 2016, is presented in figure no. 4.

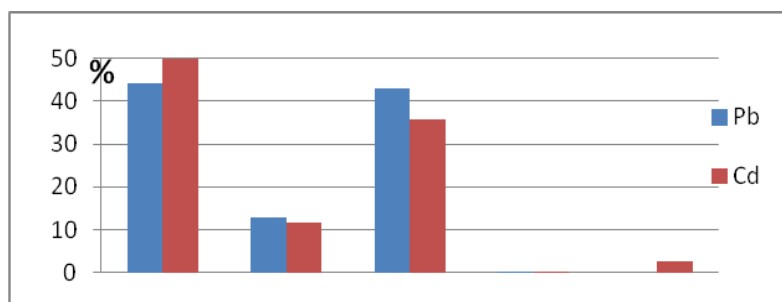


Fig. 4. The contribution of vehicle types to heavy metal emissions in Hunedoara County (Source: Environmental reports 2003-2016, APM Hunedoara)

The transport emissions of Pb come mainly from passenger cars (44.18%) and heavy vehicles (42.88%), the rest being: light vehicles (12.80%) and mopeds (0.14%). In the case of Cd, the highest contribution is given by cars (49.79%), followed by heavy vehicles and buses (35.75%), light vehicles (11.74%), railways (2.55%) and mopeds (0.17%).

Emissions of heavy metals in Hunedoara County, estimated between 2003 and 2016 by the CORINAIR and AP-42 methods, and as of 2009 according to the latest EMEP/EEA Air Pollutant Emission Inventory Guidebook in the table 3:

Table 3. Emissions of heavy metals (kg/year) between 2003 and 2010

Hunedoara County	Year							
	2003	2004	2005	2006	2007	2008	2009	2010
Mercury emissions	2248.92	407.36	180.54	252.59	330.16	300.24	133.47	111.26
Cadmium emissions	213.07	411.22	60.64	62.65	68.07	41.93	86.30	72.74
Emissions of lead	1164.38	7546.49	7035.94	3383.91	2697.17	2122.58	982.49	1841.03
<b>Total emissions</b>	<b>3626.37</b>	<b>8365.07</b>	<b>7277.12</b>	<b>3699.15</b>	<b>3095.40</b>	<b>2464.75</b>	<b>1202.26</b>	<b>2025.03</b>

Source: own projection

The above table shows a decrease in heavy metal emissions since 2009 compared to previous years, as this year was applied the CORINVENT 2009 calculation methodology that provides for different emission factors.

## 5. Conclusions

Air quality in Hunedoara County continues the general trend of improvement in recent years. Pollutant monitoring is a necessary part of any environmental management system, which is the basis of a fully-informed decision-making process and the development of environmental management strategies.

Since, at the level of Hunedoara County, the energy sector brings a significant contribution to the pollutant emissions, the rehabilitation of the energy blocks will lead to the reduction of atmospheric emissions. Supporting, enforcing and enforcing corrective measures leads to streamlining the control process, but also to the quality of environmental investments, including the performance of efficient management and the achievement of notable financial performance.

The level of emissions of pollutants released into the atmosphere can be significantly reduced through the implementation of environmental policies and strategies as follows: greater use of renewable energy sources (wind, solar, hydro, geothermal, biomass); replacing classic fuels with alternative fuels (biodiesel, ethanol); the use of high energy efficiency installations and equipment (low consumption, high yields); implementing a program for afforestation and creation of green spaces (CO<sub>2</sub> absorption, fine dust retention, oxygen release into the atmosphere). The objectives of the monitoring systems also include aspects related to process optimization, verification and compliance with legislative provisions, such as admissible emission limits. Many pollutants known to have effects on human health gradually fall under regulated control.

## **References**

- Căpușneanu, S., Ivan, R., Topor, D.I., Oprea, D.-M., Muntean, A., *Environmental Changes and their Influences on Performance of a Company by Using Eco-dashboard*, Journal of Academic Research in Business and Social Sciences, (2015).
- Constantin (Oprea), D.M., *Relația climă-poluarea mediului înconjurător în arealul municipiului Slatina*, Universitară, Bucharest, (2013).
- \*\*\* Law no. 278/2013 on industrial emissions transposing the Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on industrial emissions (Integrated Pollution Prevention and Control) (2010).
- \*\*\* <http://www.arcelormittalhunedoara.ro>
- \*\*\* National Institute of Statistics, *Statistical Yearbook of Romania* (2012).
- \*\*\* <http://www.anpm.ro>

# Influence of Thermal Conditions in a Quarry on the Local Climate

Pavla Hlavatá<sup>a</sup>, Karla Meixnerová<sup>b</sup>, Vladimír Horák<sup>b\*</sup>, Jan Kosek<sup>b</sup>

<sup>a</sup>Brno University of Technology, Antonínská 548/1, 601 90 Brno, Czech Republic

<sup>b</sup>University of Defence in Brno, Kounicova 65, 662 10 Brno, Czech Republic

---

## Abstract

The main topic of the study is to observe the impact of the quarry on the local climate, particularly on the temperature conditions in the quarry and its influence on a local precipitation in the surroundings. This influence is based on the assumption that the relief of quarry mining area together with thermal circumstances and weather conditions influences the formation of the thermal air currents. The temperatures in the quarry are monitored by temperature loggers. The temperature distribution on the mining quarry wall surface is measured by a thermal imager in various atmospheric conditions. The surface temperature and the wind vector, together with the relief of the quarry and surrounding landscape, are the input parameters for the numerical simulation of airflow, which allows us to visualize thermals.

*Keywords:* Quarry; local climate; CFD simulation; thermals.

---

## 1. Introduction

Every quarry and the impact of mining activities there cause a remarkable impact on the landscape and the surrounding environment. The location of the examined quarry in the landscape is shown in Fig. 1. There are various impacts connected with the mining area, for example blasting, transport of blasted material, development and distribution of dust particles, changes in hydrologic conditions and relief, the impact on fauna and flora in the surroundings, the impact on the local climate conditions etc. Defining and quantifying these impacts is a very complex problem.

The paper is focused on the determination of a possible impact of the quarry on the local climate conditions. The problem includes an analysis of temperature conditions and local precipitations in the given quarry and its surroundings. The presented research covered a continuous measurement of temperatures in the quarry by the temperature loggers. Their location in the quarry is shown by red marks in Fig. 1. The temperature distribution on the quarry surfaces was measured by a thermal imager in various atmospheric conditions.

Local precipitations in the quarry surroundings were measured by 22 rain gauges. Their location is shown by green marks in Fig. 1. One of the goals of the research is to find out if the local precipitations are influenced in various distances from the quarry. This influence is considered as a hypothesis that the relief of mining area of the quarry and the surrounding landscape in combination with temperature and meteorological conditions forms rising thermal columns. A computer simulation of the airflow in the quarry was chosen as a method how to assess the conditions of formation and the influence of these rising thermal columns.

## 2. Temperature conditions in the quarry

Due to uncovering the rock wall surfaces, the change in the quarry temperature conditions occurs. The change in the character of heat exchange causes the increase in heat transfer of the surfaces' temperature and consequently the increasing of the quarry air temperature in the comparison with the surrounding atmospheric temperature. The consequence of this heat transfer influences the formation of convective rising air currents.

---

\* Corresponding author. Tel.: +420 737903709

E-mail address: vladimir.horak@unob.cz

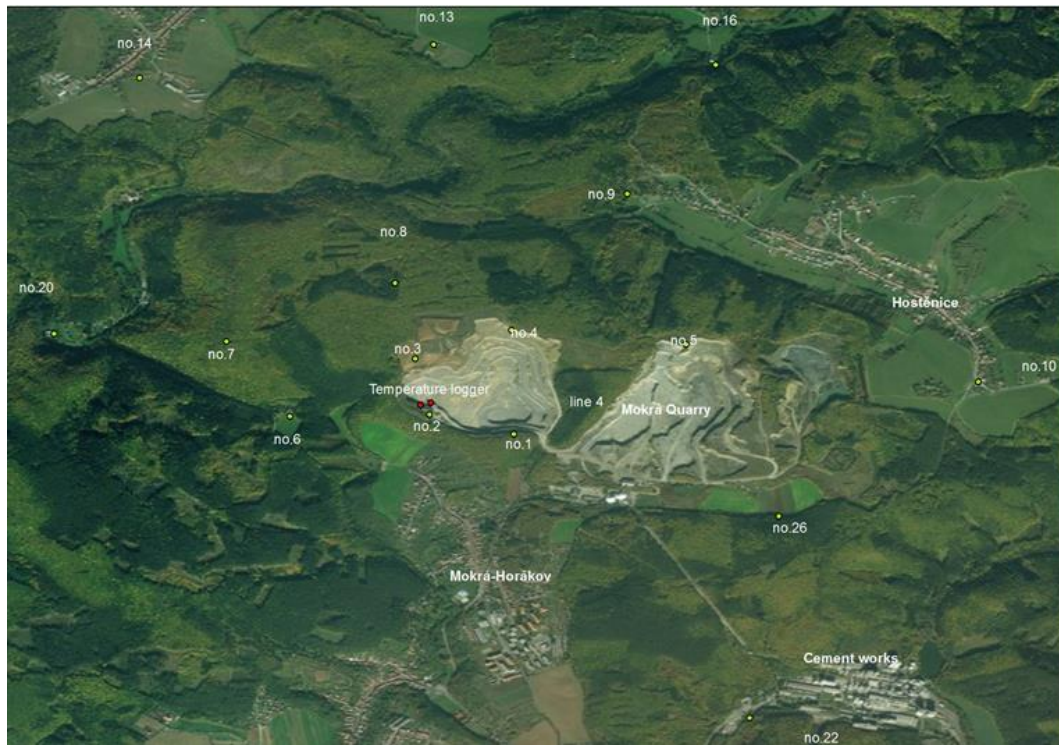


Fig. 1. Distribution of rain gauges and temperature loggers in the quarry and its surroundings

### 2.1. Air temperatures in the quarry

Air temperature analysis includes the mutual relation between the air temperature in the quarry and the ambient atmospheric temperature. The air temperature in the quarry was monitored continuously from the 2<sup>nd</sup> June to 12<sup>th</sup> September 2016 by temperature data loggers GAR 171 in two chosen places, see Fig. 1. One temperature sensor  $t_1$  was situated closely to the uncovered rock surface and the second temperature sensor  $t_2$  was situated in the distance about 20 meters away in a low vegetation.

The results of the air temperature courses measured in the quarry during the month of July are shown graphically in Fig. 2. Together with the given temperatures is plotted the atmospheric temperature course taken from the available data, measured at the near Brno-Tuřany Airport. Here we can observe differences among the mentioned temperatures.

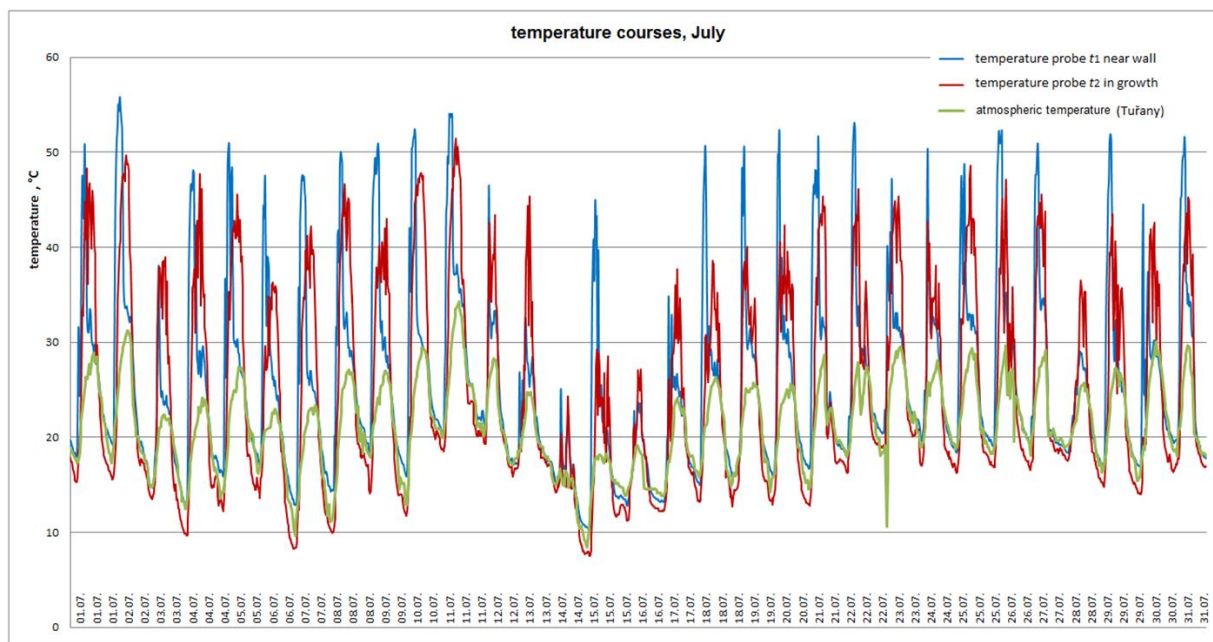


Fig. 2. Air Temperatures in the quarry during July 2016



## 2.2. Temperature of surfaces in the quarry

Increased temperatures of rock wall surfaces cause a convective air heating in the quarry. The temperature distribution across the mining surface was measured by the thermal imager FLIR T640 under various weather conditions. An example of the measured temperature distribution is given in Fig. 3. The temperature gradient of surface temperature – air temperature – atmospheric temperature causes the convective rising air currents called thermals.

Due to the computer simulation of thermals, we need to know the temperature distribution on the chosen section of the quarry walls along the direction of the wind vector. Software Workswell CorePlayer allows us to analyse accurately the infrared images. A print screen from determination of the temperature distribution along a line in the infrared image is shown in Fig. 3 in the upper part of the figure. In the lower part of the figure, there is plotted the course of temperature along the desired line in pixels. Here, we can observe various phenomena like an influence of incidental angles of solar radiation, shading of spaces, the absorption of solar radiation in forest canopies.

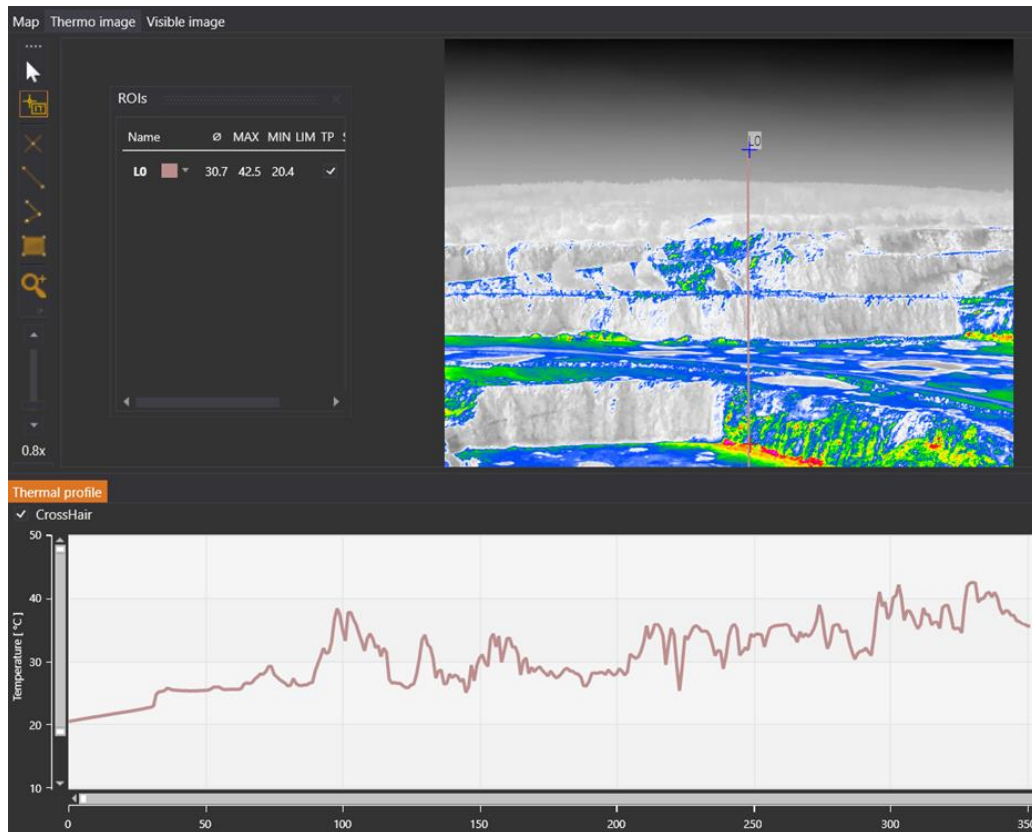


Fig. 3. Workswell CorePlayer software processing of thermal image along the chosen line in the quarry on 27<sup>th</sup> August 2016 at 1 pm

## 2.3. CFD simulation of thermals

The CFD (computational fluid dynamics) simulation of thermals was realized by use the ANSYS Fluent, which solves tasks using the finite element method of Reynolds equations derived by averaging the Navier–Stokes equations. Equation solver system was set to mode coupled with discretization of the second order. The key moment for solving these equations was the choice of turbulence model, which was chosen from a variety of models. The k-ε and SST-OMEGA turbulence models were used together with the method of Boussinesq hypothesis.

The following boundary conditions were chosen for the simulation of thermals in the quarry:

- Wind speed: calm and 5 m/s
- The atmospheric air temperature 20 °C
- The average surface temperature of 50 °C and 30 °C in the quarry
- The temperature of the forest cover is equal to the atmospheric temperature
- Material constants are the limestone for quarry area and the wood for forest area

For the purposes of the CFD simulation, the three-dimensional model of the investigated terrain was created by using the SolidWorks software, see Fig. 4. For the chosen direction drawn by the green line in Fig. 4, the two-dimensional profile of the terrain was extracted, as shown in Fig. 5. The airflow simulation was realized for wind directions from south to north and from north to south, see Fig. 5.

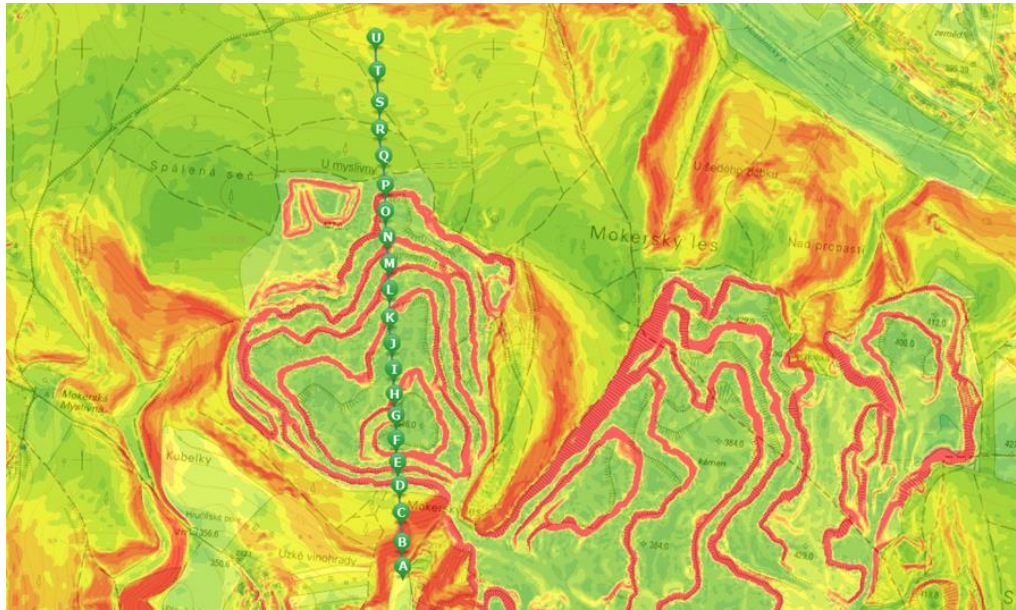


Fig. 4. Investigated terrain with marked line for the CFD simulation

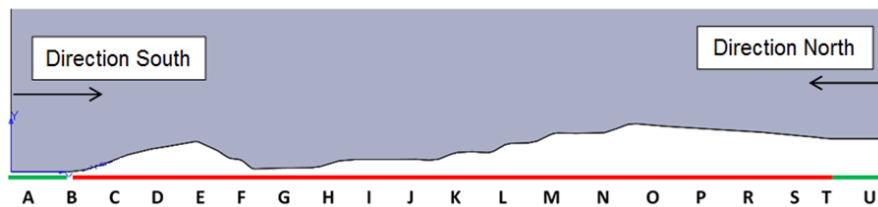


Fig. 5. Altitude relief of the chosen terrain cross-section

Examples of the resulting airflow simulation in the quarry when it is calm are given in Fig. 6 in two modes of display – for the temperature distribution and for the velocity streamlines. In these views, we can observe the typical thermal bubble, which can be understood as the volume of air, resembling the shape of a sphere. From the velocity streamlines, it is clear how this bubble moves upward. When the moist air climbs to a height below the dew point, moisture will begin to condense, the upward movement will stop and cumulus clouds start to form. Therefore, this phenomenon should not decrease rains around the quarry in a calm weather, except the case of an extremely dry air.

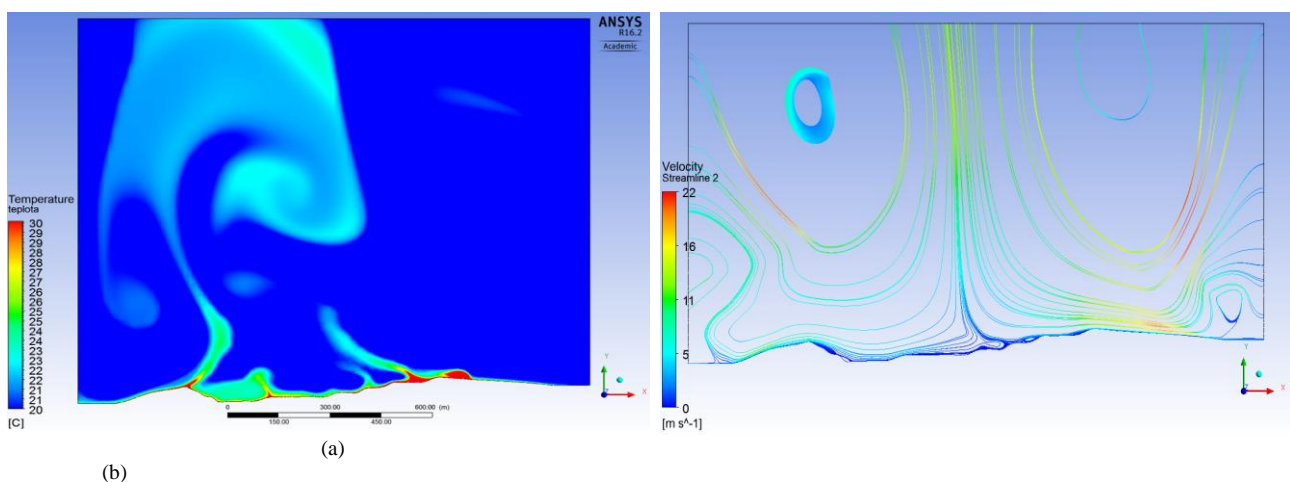
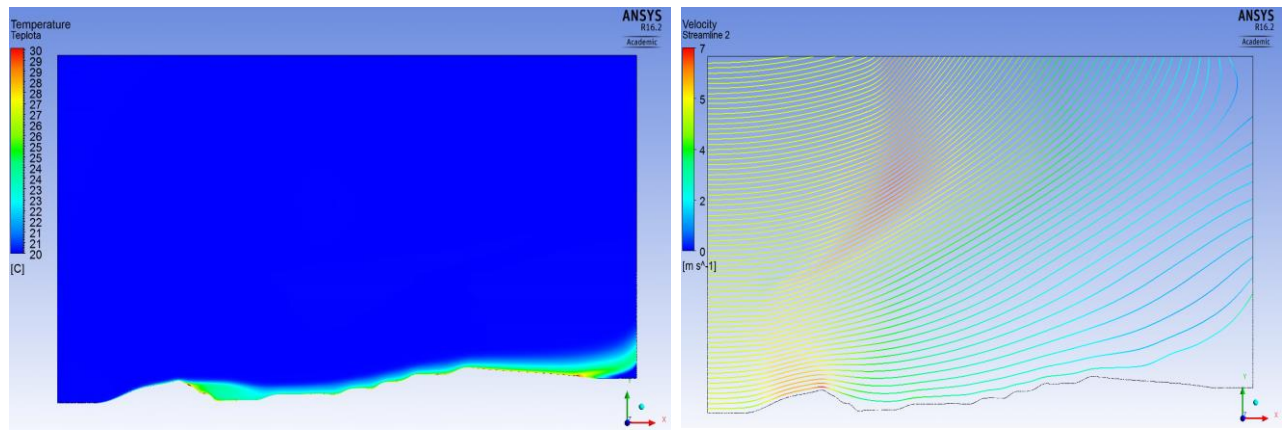


Fig. 6. Simulation of airflow in calm weather: (a) temperature distribution; (b) velocity streamlines

The results of simulation of the airflow in the quarry for the wind speed of 5 m/s are given in Fig. 7, where the temperature distribution and the velocity streamlines are shown. Here, we can observe that in this case of wind speed, rising thermals should not substantially affect the upper atmosphere, where the clouds are forming or where the rain is coming from.



(a)

(b)

Fig. 7. Simulation of airflow, wind speed 5 m/s from the south: (a) temperature distribution; (b) velocity streamlines

As the quarry and surrounding landscape are rugged, the formation of precipitation is also affected by a terrain relief. According to the British meteorologist John Sawyer an amount of orographic precipitation depends on three factors:

- Temperature and moisture characteristics of air masses and the nature of the pressure field in the synoptic scale
- Microphysical processes in clouds and evaporation of falling raindrops
- Local vertical motions induced by relief

In our latitudes, the most common types of clouds are as follows: Nimbostratus, Altostratus, Stratocumulus, Cumulus and Cumulonimbus. Since the last three types of clouds are of the cumulus cloud types, they are associated with the occurrence of storms from the heat - i.e. a local phenomenon, we decided to exclude them as they could distort our research. Therefore, we paid attention only to the low clouds (Stratus) and to the middle layer (Nimbostratus and Altostratus). These clouds occur in a range of altitudes 1-3 kilometers above the ground.

### 3. Precipitation measurement

The precipitation was measured by the standard rain gauges continuously during the summer months of 2016. It should be noted that the summer of 2016 was highly moist for our latitude. The numbered rain gauges were placed around the quarry in three distances, see Fig. 1. The first group of rain gauges (namely numbers: 1-5) was placed on the edge of the quarry. The second group of rain gauges (numbers: 6-16, 20, 22, and 26) was situated in the quarry surrounding at distance about 1-3 km from the quarry border. The last rain gauges (numbers: 11, 18-19, 21, 23, and the Brno-Tuřany Airport) were located at a greater distance about 7-9 km from the quarry.

For the purposes of better illustration, the average precipitation for each month was calculated and compared in different distances from the quarry (the edge of the quarry, the quarry surroundings and a greater distance), see Fig. 8. However, no unambiguous tendency of the quarry influence can be observed here.

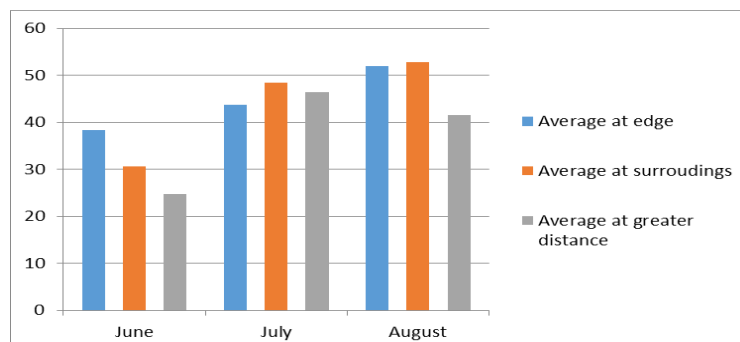


Fig. 8. Comparison of average total precipitation in mm for different distances from the quarry

The more detailed overview is given in Fig. 9, where the daily readings during the summer 2016 are plotted for chosen rain gauges (numbers: 1, 2, 6, 7, 20, and 23). These rain gauges are located on a line from the quarry edge to a distance of 12 km, see Fig. 1. However, not any tendency of quarry influence on precipitation can be found here also.

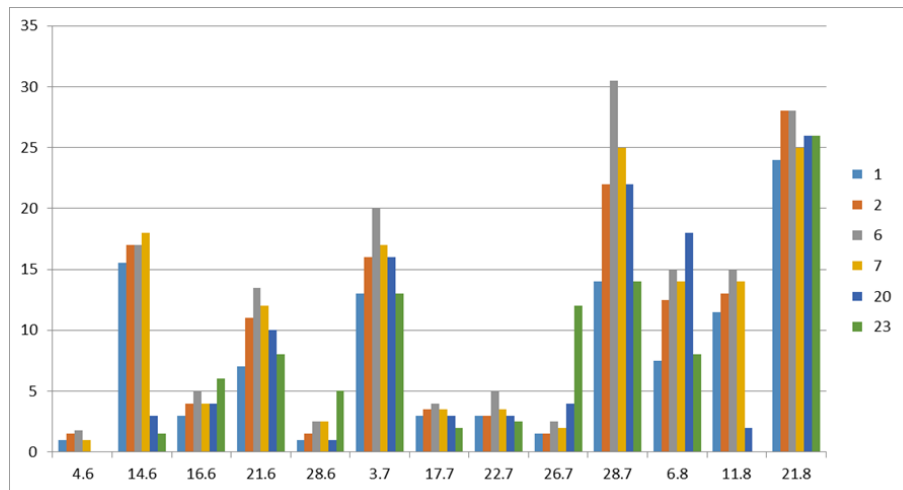


Fig. 9. Daily readings for chosen rain gauges, which are located on a line from the quarry edge to a distance of 12 km

#### 4. Conclusion

The presented project was focused on the study of a possible impact of the Mokrá quarry on the local climate conditions.

There were quantified increased temperature conditions at the quarry area during the summer months 2016. It was found that the air temperatures inside the quarry are substantially higher comparing to the surrounding atmospheric temperature during sunny days. Further, the thermal imaging allowed us to identify the most thermally exposed quarry sites.

The increased temperature conditions cause creation of thermals. The computer simulation was used for the visualization and study of the airflow in the quarry. It was found that thermals could influence the upper atmosphere only in a calm and in very hot weather.

Measuring of precipitation during the summer months 2016 in various distances from the Mokrá quarry did not prove the influence of the quarry on the local precipitation. It should be noted that more generally valid conclusions would require a longer measurement in more consecutive years.

Regarding to the relatively small uncovered area of the Mokrá quarry, its influence on the local precipitation will be minimal. The quarry area is very small in comparison with a large urban agglomeration, such as e.g. the city of Brno located nearby the Mokrá quarry. The landscape around the Mokrá quarry is very different from high mountain massifs, which could cause a rain shadow as well.

A rather limited time for the project caused that some problems are only outlined in the paper. Therefore, some future studies are planned. Namely, it is a comprehensive computer simulation of thermals for various terrain situations and weather conditions.

#### Acknowledgement

The work presented in this paper has been supported by the specific research project of Faculty of the Military Technology SV18-216, University of Defence in Brno and by the project the Quarry Life Award, Heidelberg Cement.

#### References

- User's Manual. Flir T6xx series.* Flir Systems, Wilsonville, (2013). Available from: <https://www.instrumart.com/assets/FLIR-T620-T640-Manual.pdf>
- User Manual, CorePlayer&CoreLibrary, Revision 1.4,* Workswell, Prague, (2015). Available from: [http://www.workswell.cz/manuals/CorePlayer\\_user\\_manual.pdf](http://www.workswell.cz/manuals/CorePlayer_user_manual.pdf)
- ANSYS Fluent User's Guide, Release 15.0,* ANSYS, Inc. Southpointe, (2013). Available from: <http://148.204.81.206/Ansys/150/ANSYS%20Fluent%20Users%20Guide.pdf>
- Bednar J., Zikmunda O., *Physics of the Atmospheric Boundary Layer.* (in Czech), Academia, Prague, (1985).
- Sawyer, J.S., *Cooling of Air by Rain as a Factor in Convection,* Professional Notes, No. 96, Meteorological Office, London, (1949).



# Substantiating the decision regarding the ecological reconstruction of mining waste dumps – case study for Lupeni dump

Faur Florin<sup>a\*</sup>, Lazăr Maria<sup>a</sup>, Nyari (Apostu) Izabela-Maria<sup>a</sup>

<sup>a</sup>University of Petrosani, University street, no. 20, Petrosani, 332006, Romania

---

## Abstract

According to EC Decision No. C (2018) 1001 final, at the end of this year, productive activity at Lupeni Mining Exploitation will cease, and from the beginning of next year the ecological reconstruction of the site will be started. In this context, the ecological reconstruction of the mining waste dump (branch III), active at the moment, is also under consideration. In the present paper we intend to establish the optimal alternative of ecological reconstruction using a methodology proposed and published in the literature. This methodology makes it possible to identify the optimal alternative of ecological reconstruction (and to eliminate inopportune ones) by following three phases, in a logical sequence, in which a number of factors and indicators characterizing both the site area (the climate of the region, the morphology, the environmental risks etc.) as well as the degraded land (the waste dump), especially in terms of fertility of the stored material. In this way the risk of making an erroneous decision (on the ecological reconstruction option) that does not meet the proposed objective and at the same time may cause unjustified expenses is minimized.

*Keywords:* ecological reconstruction, methodology, mining, waste dumps

---

## 1. Introduction

Ecological restoration and reuse of degraded lands must contribute to the region's sustainable development, therefore, in order to determine the land destination post degradation, a number of opportunities and restrictions should be taken into account. For this reason, a methodology was developed to establish the optimal reuse type, based on scientific principles, without neglecting economic issues and those related to population requirements (Lazăr et al., 2017).

To obtain the desired results, the type of ecological restoration chosen must match local conditions expressed by restrictions related to the geographical position and must take into account a number of principles of ecological planning (McHarg, 1969): 1. The principle of globality or inter-causality; 2. The principle of ambient autonomy; 3. The principle of minimum sizing and reversibility; 4. The principle of economy; 5. The principle of respect for tradition; 6. The principle of transparency and democracy; 7. The principle of respect for the demands of the population.

Having in regard the above and considering the numerous ecological reconstruction projects that failed it was seen as necessary to apply the developed methodology in order to substantiate the decision regarding the ecological reconstruction of Lupeni mining waste dumps.

## 2. Brief description of the methodology

This methodology follows 3 phases, ordered logically, briefly described below:

*Phase I* - the initial consultation of the public and decision factors (the current owner of the land, local, county or regional administration, etc.). This first phase takes into account principles no. 5, 6 and 7 and was materialized in the form of public debates (Lazăr et al., 2017). In this phase there were identified the possible types of ecological reconstruction of the waste dump.

---

\* Corresponding author. Tel.: +4-072-446-1601.

E-mail address: faurfloring@yahoo.com.

*Phase II* - implements into the decision-making process the principles no. 1, 2, 3 and 4. For this purpose a number of characteristics and indicators of major importance in the process of ecological reconstruction of the degraded land must be taken into account (temperature, precipitations, wind regime, inclination of the land, physical stability, accessibility, presence of permanent water sources, flooding, vegetation wildfire and seismicity) (Lazăr et al., 2017).

For each characteristic and indicator there were assigned scores according to the methodology. The total points obtained for each proposed type of ecological restoration being calculated by summing on each row (each indicator must obtain the minimum score required) and then are multiplied for each project with the appropriate economic coefficient, resulting equivalent scores (Lazăr et al., 2017).

By applying the procedure described above, the proposed ecological restoration projects can be grouped into four opportunity classes based on the equivalent scores obtained (Lazăr et al., 2017): 2 - 12 points - inappropriate projects; 13 - 23 points - projects with reduced opportunity; 24 - 34 points - projects with medium opportunity; 35 - 45 points - projects with high opportunity. At this point only the projects within the high opportunity class (or the same class of opportunity) are further considered.

*Phase III* - the projects that have passed phase II starts from scratch (the scores from phase II are no longer considered). To evaluate and separate the ecological reconstruction projects that passed phase II, a series of fertility indicators and the possible presence of undesirable elements were considered (incompatible with productive restoration, that should also be considered for recreation or leisure restoration): soil structure, soil reaction, nutrients (primary macronutrients - N, P, K; secondary macronutrients - S, Ca, Mg and micronutrients - Fe, Mn, B, Zn, Cu, Mo, Co), humus content, C/N ratio, excess sodium (SAR index), excess of soluble salts, heavy metal content (Lazăr et al., 2017).

By summing the scores attributed to each indicator for each project (while achieving the minimum required score for each indicator) they can be grouped as follows: 0 - 10 points - projects with reduced opportunity; 11 - 20 points - projects with medium opportunity; 21 - 30 points - projects with high opportunity.

After this selection, in terms of opportunity, the projects within the same group can be prioritized in accordance with the individual score and available financial resources (Lazăr et al., 2017).

### 3. Description of the waste dump and surrounding area

#### 3.1. The waste dump (branch III)

Lupeni mining perimeter is located in the municipality with the same name, in the western part of the Jiu Valley mining basin. The waste dump (formed of three branches) is located 4 km from the main enclosure in a hilly area, with heights ranging from + 780 m, in the Boncii creek area, to + 960 m, on the left side of West Jiul river (HEC, 2015).

Auto access to the dump is limited, with 4x4 vehicles, or pedestrian on steep slopes.

The Lupeni waste dump (branch III) occupied an area of 16.64 ha and a volume of 2,102,620 tons (1,336,827 m<sup>3</sup>) at the end of 2016, with no foreseen expansion, and its development is in a single step (the designed capacity of the dump was of approximately 2,387,800 m<sup>3</sup>).

Branch III of the dump consists of two bodies, A and B, that should have been joined in longitudinal section, one of prismatic form located between the pillars P4 and P6 (in conservation for about 11 years and vegetated) and a conical-shaped dumping body in the common area of the three branches, where the sterile material is currently dumped (between the angular station and the P1 pillar). In this paper only the B body is considered.

The waste dump has varying heights depending on the morphology of the terrain and the deposition area.

For the conical-shaped B body (Figure 1), to satisfy the technological and stability aspects of the slopes, a height of 30 - 35 m and a slope angle of 37° - 39° were adopted. These characteristics are obtained by arranging a leveling platform at elevation + 837.5 (access road elevation) by pushing the material with a bulldozer, lateral to the funicular axis towards the common dumping area (HEC, 2015).

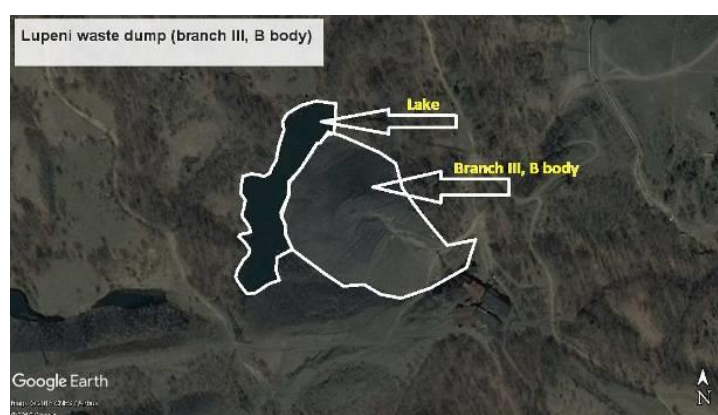


Fig. 1. Lupeni mining waste dump (branch III, B body)

At the contact with the natural terrain, in the longitudinal profile of the funicular axis, a lake is formed (Figure 1). The infiltration of water into the pores of the rocks at the base of the waste dump, leads to a decrease of the resistance characteristics and the risk of landslides (Lazăr et al., 2014).

Moreover, in a study conducted in 2017 it is shown (through the stability analyzes performed with the help of a specialized software) that, practically, in the current geometrical configuration, the slope of the waste dump (being in contact with the lake) is close to the stability (equilibrium) limit. The values of the stability coefficient, determined by Fellenius method, vary between 1.054 and 1.085 (shows a stability reserve between 5.4 and 8.5 %) (Stretenie, 2017).

The deposited material comes from the sorting process that takes place at the surface, in the separation section, respectively from mining works (opening, preparation and exploitation).

It consists of a heterogeneous mixture of soft rocks (clays and marls) and hard rocks (sandstones) with an increased unevenness of granulometry and physico-mechanical properties (Table 1). To these are added coal fragments and alluvial deposits (boulders, gravels and sands) that formed the major bedrock of the West Jiul river.

Table 1. Variation limits for the physical and mechanical proprieties of the deposited rocks

No.	Specification	Measuring unit	Variation limits
1.	Granulometry		
	- clay (under 0,005 mm)	%	2.10÷4.20
	- dust (0,005 – 0,05 mm)	%	2.10÷5.10
	- sand (0,05 – 2,0 mm)	%	13.20÷18.90
	- gravel (2,0 – 20 mm)	%	39.10÷40.90
	- boulder (over 20 mm)	%	44.20÷45.30
2.	Specific weight	kN/m <sup>3</sup>	25.30÷26.10
3.	Volumetric weight	kN/m <sup>3</sup>	17.60÷18.10
4.	Natural humidity (moisture)	%	13.87÷16.88
5.	Porosity	%	39.83÷41.23
6.	Pore index	-	0.66÷0.70
7.	Cohesion	kN/m <sup>2</sup>	32.21÷34.11
8.	Internal friction angle	°	24.00÷28.00
9.	Compressibility coefficient	cm <sup>2</sup> /daN	1.50÷1.51
10.	Specific compression	daN/cm <sup>2</sup>	6.70÷6.90

The collected samples were also analyzed from the point of view of the chemical composition and the presence of nutrients. These analyzes are necessary to determine the capacity of the waste material to support vegetation and score points in Phase III of the methodology. The results of these analyzes (mean values) are presented in Tables 2 and 3.

Table 2. Chemical composition of the deposited material

Waste dump	Determined parameter								
	pH	SiO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub>	Fe <sub>2</sub> O <sub>3</sub>	MgO	CaO	Na <sub>2</sub> O	K <sub>2</sub> O	Volatile
Lupeni – branch III		(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
	7.32	63.45	10.51	2.23	0.84	0.79	0.96	1.55	19.67

Chemical analyzes show a virtually neutral pH value and do not indicate the presence of elements that could affect human health or would not allow vegetation to develop. The neutral pH value also eliminates the need for additional neutralization works before starting the actual ecosystem restoration.

Table 3. Content of nutrients

Element	Humus	N	P	K	S	Ca	Mg	Fe	Mn	B	Zn	Cu	Mo	Co
	-	Primary macronutrients			Secondary macronutrients			Micronutrients						
Measuring unit	%													
Concentration	2.87	0.35	0.044	1.55	0.21	0.79	0.84	2.23	0.029	-	0.008	0.01	-	0.002

Fertility parameter analyzes indicate low content of macronutrients (primary and secondary) and low to medium micronutrients. From this point of view the land allows the spontaneous installation of species which are present in the areas adjacent to the waste dump and are unpretentious to the soil (especially birch, wild rose and herbaceous species).



### 3.2. Characteristics of the surrounding area

The evolution of the air temperature during the year is determined by the annual variation of the solar radiation and the air circulation regime, having a maximum in July of 14.5°C and a minimum in January of -5.2°C. In the annual air relative humidity regime, there is a main peak in December (93 %) when the air temperature is low and the minimum is recorded in March-April (77 %). Atmospheric precipitations decrease on average from west to east, they rise with altitude and have an irregular rhythm (Faur, 2009). Table 4 shows the average monthly multiannual temperatures (°C) and monthly and annual quantities of atmospheric precipitation (mm) for Lupeni and Straja.

Table 4. Monthly and annual average temperatures and precipitations

No.	Month Station	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Annual average/total
Temperatures (°C)														
1.	Lupeni	-4.5	-2.3	2.2	7.1	11.6	15.0	16.7	15.9	12.1	7.4	2.4	-2.0	6.8
2.	Straja	-5.8	-4.8	-2.3	1.9	7.1	10.4	12.4	12.3	9.1	5.1	-0.9	-3.7	3.4
3.	Average	-5.2	-3.5	-0.5	4.5	9.4	12.7	14.5	14.1	10.6	6.2	0.8	-2.8	5.1
Precipitations (mm)														
4.	Lupeni	37.1	14.9	41.8	51.6	80.3	106.4	61.8	61.8	54.7	52.2	44.4	41.3	693.7
5.	Straja	61.9	49.9	58.7	107.0	93.8	124.2	64.6	64.6	66.4	84.1	66.4	55.6	951.5
6.	Average	49.5	42.4	50.2	79.3	87.0	103.0	63.2	63.2	60.6	68.2	55.4	48.5	822.6

The months with the highest rainfall are June and July. Frequency of torrential rains is low. There are no periods of severe drought and the average atmospheric humidity is 4.59 l/mm<sup>3</sup>.

The wind regime is characterized by a calm period (38 %) and a windy one (62 %). The most frequent winds are from southwest (16.5 %), followed by warm winds from southeast (14 %). Winds from west have the highest intensity, but they are less frequent (4 % of the time) and often cause damages by breaking down or plucking trees from the forests (Faur, 2009). On Beaufort scale, the wind strength ranges from 1 to 4 (over 95 % of the windy period).

The land can be affected by floods only under special conditions (sudden melting of high amounts of snow combined with abundant liquid precipitations).

Vegetation wildfires, caused by natural causes, have not been reported in the region, only small man-made fires that run out of control.

From seismic point of view, according to P100-1 - seismic design code - part I, the peak values of ground acceleration are between 0.10g and 0.15g ( $g = 9.81 \text{ m/s}^2$ ) and the control period is 0.7 (MO, 2013).

## 4. Applying the methodology

As stated before the methodology involves three phases, allowing in the end to identify the optimal ecological reconstruction type for the degraded land in question.

### 4.1. Phase I

The identification of possible alternatives for ecological reconstruction of Lupeni dump - branch III, B body was made through questionnaires and discussions with the inhabitants of the municipality. The questionnaires were distributed with the help of the mayoralty, which later facilitated discussions with the inhabitants interested in the project (Corui et al., 2004). Following this approach, four main directions of ecological reconstruction (one with two variants) materialized:

- **Naturalistic recovery** - aiming to recreate the natural landscape, including specific measures for environmental protection;
- **Recreation and sports (practicing mountain biking and motocross)** – to a certain extent is similar to naturalistic recovery, in addition providing specific structures for leisure and sports;
- **Productive restoration** - orchard plantations, namely *Prunus domestica* sp. (plum tree);
- **Productive restoration** - forestry plantations. There were proposed two main species, namely *Pinus sylvestris* (pine tree) or *Fraxinus excelsior* (ash tree).

Further in the text the following abbreviations will be used: naturalistic restoration – NR; recreation and sports – RS; productive for forestry – PF; productive for orchards – PO.

In order to be able to complete the next phases, a brief description of the requirements of each proposed tree and forest species is needed:

*Prunus domestica* sp. - height up to 10 m. Arbor or shrub with superficial roots. The leaves are elliptic, finely chopped-serrated, white-green flowers (grouped 2 - 5), elongated fruit of different colors from yellow to black-bluish. It blooms in April-May. It requires soils with medium to high fertility, southern exhibition, average temperatures in the blooming months of 6 - 10°C, and those of fruit baking of 15 - 16°C. It is the most common fruit tree in Romania. (Pârvu et al., 1985).

*Pinus sylvestris* - up to 40 - 50 m in height. It has a pyramidal crown in its youth and irregular in maturity. The bark is brick-reddish, acicular leaves (4 - 6 cm), brown-gray cones (about 7 cm). It blooms in May-June. It is very tolerant to temperature and precipitations, it develops on poor, skeletal soils and on peatlands, with a pH from acid to weakly basic (Pârvu et al., 1985).

*Fraxinus excelsior* - height up to 40 m. The leaves are composite feathered, serrated. Nude flowers, packsaddle fruits, it blossoms in April, before it's leaves appear. Used for furniture, musical instruments, etc. It develops on plains and hilly areas and requires fertile soils (medium to high), well-structured, moist, rich in calcium, with a weakly to medium basic pH (Pârvu et al., 1985).

#### 4.2. Phase II

In the second phase the proposed projects are evaluated in relationship with the characteristics of the surrounding area and some physical characteristics of the waste dump - branch III, B body: C1 - temperature, C2 - precipitations, C3 - wind regime, C4 - inclination, C5 - stability, C6 - accessibility, C7 - permanent water sources, C8 - flooding, C9 - vegetation wildfires, C10 - seismicity (presented in paragraph 3) and the demands of the tree species (presented in paragraph 4.1). Following this evaluation scores are attributed for each project according to the methodology (Lazăr et al., 2017) and the initial selection matrix (matrix A) for ecological restoration options is completed (Table 5).

Table 5. Matrix A – initial selection of the ecological restoration options

Type of ecological restoration	Indicator										Total points
	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	
NR	3	3	3	1	1	1	3	2	3	3	23
RS	3	3	3	1	1	1	3	2	3	3	23
PF – Pine tree	3	3	3	1	1	1	3	2	3	3	23
PF – Ash tree	3	3	3	1	1	1	3	2	3	3	23
PO – Plum tree	2	3	3	1	1	1	3	2	3	3	22
Relative importance of the indicator to the ecological restoration project											
Major importance – minimum accepted 2 points											
Medium importance – minimum accepted 1 point											
Low importance (relatively unimportant) – 0 points accepted											

As can be seen from Matrix A, two of the proposed types are eliminated because the minimum score required by the methodology for C5 - stability and C6 - accessibility are not obtained. These are RS and PO - plum orchard (for PO, C1 - the temperature is also at the limit).

By multiplying the total points with the economic coefficients assigned to each type of ecological reconstruction (Lazăr et al., 2017) the following equivalent scores are obtained: NR = 23 x 1 = 23 - **reduced opportunity**; PF – pine tree = 23 x 1.25 = 28.75 - **medium opportunity**; PF – ash tree = 23 x 1.25 = 28.75 - **medium opportunity**.

Following this evaluation, only the two projects, falling in the medium opportunity class, will pass into the third phase.

#### 4.3. Phase III

In order to be evaluated at this stage the two projects, starting from zero, we took into account those presented in paragraphs 3.1 and 4.1 (the characteristics of the waste material and the conditions claimed by the tree species proposed for the ecological reconstruction of the waste dump: I1 – soil structure, I2 – soil reaction, I3 – primary macronutrients, I4 – secondary macronutrients, I5 – micronutrients, I6 – humus content, I7 – C/N ratio, I8 – excess of sodium, I9 – excess of soluble salts, I10 – heavy metals). Thus, by attributing scores according to on the proposed methodology (Lazăr et al., 2017) the B matrix - final selection of the ecological restoration options was constructed (Table 6).

Table 6. Matrix A – initial selection of the ecological restoration options

Indicator											Total points
	I1	I2	I3	I4	I5	I6	I7	I8	I9	I10	
Type of ecological restoration											
PF – Pine tree	1	3	3	3	3	1	1	3	3	3	24
PF – Ash tree	1	3	1	1	2	1	1	3	3	3	19
Relative importance of the indicator to the ecological restoration project											
	Medium importance – minimum accepted 1 point										

Analyzing the results in Matrix B, we can see that although both projects pass this phase (by obtaining the minimum required scores for each indicator), they fall into different classes of opportunity. Ecological reconstruction using *Pinus sylvestris* (pine tree) falls into the **high opportunity** class, while the variant with *Fraxinus excelsior* (ash tree) in the **medium** one.

This means that the optimal type of ecological reconstruction for Lupeni waste dump - branch III, B body, as determined by applying the proposed methodology (Lazăr et al., 2017), is the one using *Pinus sylvestris* (pine tree).

## 5. Conclusions

By applying the proposed methodology we were able to eliminate from the second phase three of the initially proposed projects for the ecological reconstruction of Lupeni waste dump – branch III, B body. They were eliminated either because two of them (RS and PO) failed to achieve the minimum required score for two of the mandatory indicators (C5 and C6), while the other (NR) entered into an inferior opportunity class compared to other projects (PF).

In the third phase, the difference between the two analyzed projects was given by the lower requirements in terms of fertility of *Pinus sylvestris* (pine tree) compared to *Fraxinus excelsior* (ash tree). Thus the first species requirements are closer to those offered by the stored sterile material and as a consequence it scores higher, proving to be the optimal alternative for the ecological reconstruction of the mining waste dump.

The methodology can also be adopted to solve different other situations of degraded lands often encountered (eroded lands, lands degraded by industrial processes or unsustainable agricultural practices, etc.)

## References

- Corui, A., Hojda, D., Faur, F., Calen, V., Proposed solutions for the ecological rehabilitation of branch III belonging to the waste dumps of Lupeni Preparation (in Romanian), *5<sup>th</sup> National Students Symposium "Geoecologie și Procesarea Resurselor Minerale"*, 21-22 of May, Petrosani, Romania, (2004).
- Faur, F., The Elaboration of an environmental monitoring system in Jiu's Valley (in Romanian), *Doctoral Thesis*, University of Petrosani, Romania, (2009).
- Hunedoara Energetic Complex (HEC), Technical Memorandum, *"General operation program for Lupeni Mining Exploitation"* (in Romanian), Petrosani, Romania, (2015).
- Lazăr, M., Florea, A., Faur, F., Research on load carrying capacity of base terrains of the waste dumps in Jiu Valley, *Mining Review*, Vol. 20, No. 4, pp. 26-31, (2014).
- Lazăr, M., Faur, F., Dunca, E.C., Ciolea, D.I., New methodology for establishing the optimal reuse alternative of degraded lands, *Environmental Engineering & Management Journal (EEMJ)*, Vol. 16, No. 6, pp. 1301-1308, (2017). ([https://www.researchgate.net/publication/319454791\\_New\\_methodology\\_for\\_establishing\\_the\\_optimal\\_reuse\\_alternative\\_of\\_degraded\\_lands](https://www.researchgate.net/publication/319454791_New_methodology_for_establishing_the_optimal_reuse_alternative_of_degraded_lands)).
- McHarg, I., *Design with Nature*, Natural History Press, Garden City, New York, (1969).
- Ministerial Order (MO) No. 2465/2013, for approving the technical regulation P100-1 – seismic design code – part I (in Romanian), *Romanian Official Monitor*, No. 558 from 8th of August, (2013).
- Pârnu, C., Godeanu, S., Stroe, L., *Guide in the world of animals and plants* (in Romanian), Ceres Publishing House, Bucharest, Romania, (1985).
- Stretenie, C.M., Reconstruction and restoration of the ecosystem from Lupeni waste dump – branch III (in Romanian), *Project for Bachelor of Engineering*, University of Petrosani, Romania, (2017).

# Clay liner design of a landfill in Jiu Valley based on deterministic & stochastic risk analysis

Camelia Madear<sup>a\*</sup>, Gelu Madear<sup>b</sup>

<sup>a</sup>ECO-ROCCA Engineering SRL, 23, Parcului Street, Petrila - 335800, Romania

<sup>b</sup>GOLDER, 1, South Parade, Doncaster – DN1 2DY, UK

---

## Abstract

Coal Mining Industry in Jiu Valley left some abandoned open pits which represent a significant liability to the environment. One solution for the rehabilitation of these sites would be the reuse of the open pits as landfills for Municipal Solid Wastes (MSW). The paper presents the proposed solution for the engineered barrier and leachate management system. Generated volumes of leachate were calculated based on local precipitations data using the most advanced hydrological modelling software for designing landfills and evaluating potential leachate seepage to the groundwater table, used as input parameters in Hydrogeological Risk Assessment (HRA).

*Keywords:* coal mining; landfill; open pits; environment; risk analysis; HRA.

---

## 1. Introduction

To comply with the Landfill Directive (1999/31/EC), Groundwater Directive (80/68/EEC), Water Framework Directive (2000/60/EC), Drinking Water Directive (80/778/EEC), a thorough Hydrogeological Risk Assessment (HRA) should be carried out before applying for permitting to the Environment Agency. To carry out the HRA, a Conceptual Site Model has been developed based on existing information on geology and hydrogeology, as well as mining records.

Clay liner design was based on the impact of existing contaminants in leachate to environmental receptors – the aquifer (Receptor 1) below the site within the bedrock and an imaginary borehole (Receptor 2) outside the landfill area. We have assessed the impacts for List I substances at Receptor 1 and the impacts for List II substances at Receptor 2.

The Source-Pathway-Receptor (SPR) linkages as derived from the Conceptual Site Model (CSM) were used in a multi-tiered Hydrogeological Risk Assessment.

The first phase consists of a Simple Risk Assessment using deterministic approaches. For the worst-case scenario, analytical solutions are solved in a deterministic fashion using conservative input parameters, assumptions, and methods.

The second phase uses a Complex Risk Assessment which is carried out using stochastic techniques to an analytical solution. Monte Carlo simulations are used to evaluate and predict leachate concentrations and elevations during the operational phase of the landfill and to estimate advective fluxes from the landfill. Both advection and diffusion are possible contaminant migration mechanisms throughout the lifecycle of the landfill.

The use of probabilistic distribution functions addresses the uncertainty of the input parameters, and the results are also returned as ranges and defined according to the probability of occurrence. The 95th percentile values are used as outputs from the model, which are representative of the reasonable worst-case performance of the landfill. The Romanian Drinking Water Standard has been used as the Environmental Acceptable Levels (EAL).

---

\* Corresponding author. Tel.: +40 744 60 77 38  
E-mail address: camelia.madear@eco-rocca.ro

## 2. Background Information and Site Description

Jiu Valley is known to be one of the most important mono-industrial areas in Romania, due to the coal mining industry. In addition to the benefits of this activity, the Jiu Valley is now paying a fairly high tribute to all years of exploitation, namely the acquisition of a large number of degraded land areas. However, the disadvantage of the existence of these surfaces may turn into an advantage if it is taken into account that they can serve as ecological landfills.

An example of degraded space from the mining activities in Jiu Valley, which can be a potential site for the ecological landfill, is Victoria Open Pit (VOP) in Lupeni (Fig. 1 a and b).



Fig. 1. (a) Victoria open pit; (b) Victoria open pit footprint

VOP is located approximately 2 km north-east of Lupeni City Center, in Petrosani Depression, Hunedoara County. The latitude of the centre of VOP, Jiu Valley is  $N45.3765^\circ$ , and the longitude is  $E23.2298^\circ$ , with GPS coordinates  $45^\circ22'35.4''$  and  $23^\circ13'47.28''$ . The open pit is delimited at the east by Vulcan Minefield, to the west by the Barbateni Village, having Hateg Mountains to the north and Valcan Mountains to the south. A railway runs approximately 3 km south along DN66A. VOP is within a hilly topography, in the western part being covered by dense forests and meadows to the east. Nearby, at approximately 750 m southeast and 1.5 km southwest, there are few urban areas with buildings and some minor roads serve the area and link to the site. Jiul de Vest river is located approximately 3 km south of the VOP and also two small brooks - Bolosinestilor and Plisabeia - runs nearby.

## 3. Geology, Hydrogeology and Engineering Geology

Based on the available background information, the following superficial deposits and strata are expected at the site and its environs and are described in Table 1, from the youngest to the oldest:

Table 1. Summary of geology

System – Series - Age	Formation
Neogene – Miocene - Burdigalian	Sandstone, Reddish and Greenish/ Greyish Clays, Carboniferous Schists
Paleogene – Oligocene - Chattian	Sandstones, Marls, Bituminous Marls, Disodilic Schists, Carboniferous Schists and Coals
Paleogene – Oligocene - Rupelian	Clay, Marl, Sandstone, Sandstone Containing Bituminous Clay, Coal

**Burdigalian - Hanging Wall Horizon** - This horizon is made up of a conglomeratic series in alternation with sandstones, reddish and greenish/ greyish clays, sometimes with plants and carboniferous schists. In Lupeni area there are three distinctive conglomerate layers, which divides towards the east, becoming more like sandstones, with some intercalations of marls, marly limestones, green clays and yellow sands slightly cemented.

**Chattian-Aquitania - Productive Horizon** - This geological formation is comprised of a series of micro-conglomerates, sandstones, marls, bituminous marls, disodilic schists, carboniferous schists and coals. Coals are located at various depths within this horizon and are represented by 25 layers of hard coal and brown coal. At the upper part of the horizon, there is an alteration of clays, sands, sandstones, carboniferous schists and coals.



Rupelian - Inferior Conglomeratic Horizon - Conglomerates represent approximately 75% of the total thickness of the formation comprising grey quartzitic rocks, gneiss and pegmatites, which are embedded in a reddish clay layer. On the west side of the Jiu Valley, at Lupeni, Vulcan and Uricani there are green sandstones and white-yellowish limestones distributed randomly. Rupelian deposits are located at the boundary of Petrosani Coal Basin, but there are not found on its north-western side - north of Lupeni, where Burdigalian might overlay them.

Tectonics - Petrosani Coal Basin is embedded into the tectonic ensemble of Southern Carpathians, having in its structure all the three distinct units: Getic Terranes (Nappe); Danubian Terranes (Unit); Neozoic Sedimentary Deposits. The Danubian and Getic Terranes consist of shallow-water marine and non-marine Mesozoic rocks that rest on Paleozoic and Precambrian sedimentary and crystalline rocks. The main tectonic element is represented by the fact that rocks of the Getic Terranes have been thrust eastward over rocks of the Danubian terrace, along the Getic thrust fault, resulting in a synclinal basin.

A geological cross-section and the geological map of the region are presented in Fig. 2 a and b.

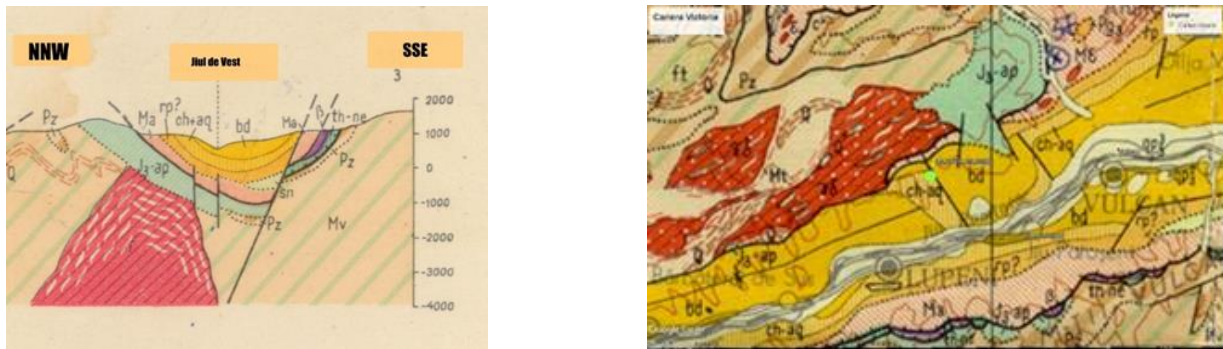


Fig. 2. (a) Geological cross-section; (b) Geological map of the region

#### 4. Quantitative Hydrological Risk Assessment (QHRA)

Victoria Landfill is proposed to be constructed to receive Municipal Solid Waste (MSW) from nearby towns. A former open-pit is now a potential location for a landfill and would be relatively small in size. Environment Agency requires that as part of the waste management licensing process, an assessment is carried out to predict the likely impact on groundwater and compliance against the requirements of the Groundwater Directive.

Separate risk assessments are to be undertaken for other processes including migration of, and exposure to landfill gases, construction and durability of engineered barriers and leachate management systems and impacts on ecological systems. A hydrogeological conceptual model (Fig. 3) has been developed based on historical mining data and groundwater levels, and the outline design of the proposed landfill.

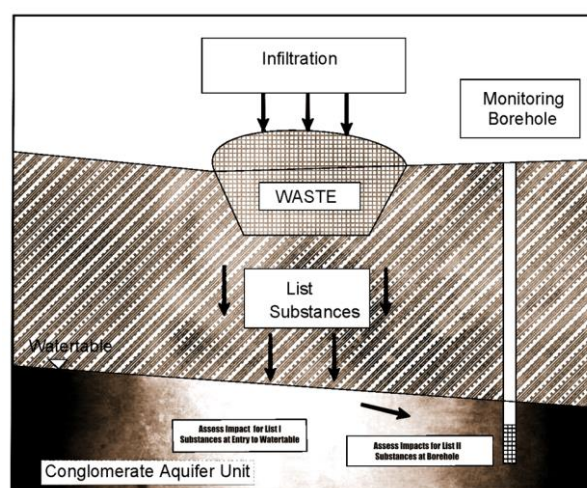


Fig. 3. Hydrogeological conceptual site model

The landfill is underlain by strata that are classified as Minor Aquifer by the Romanian Environment Agency and consists of inter-bedded clays, silts and sands. Hydraulic continuity is assumed between the sandstone horizons and is assumed to have a saturated aquifer hydraulic conductivity between  $1.0 \times 10^{-5}$  m/s and  $3.4 \times 10^{-6}$  m/s. The regional hydraulic gradient is 0.05 towards the SSE, to Jiu de Vest river.

The winter watertable lies at an average of 5 m below the site, and effective rainfall is estimated at approximately 692.8 mm/ year based on Meteo Parang Weather Station.

The potential source of pollution is contaminants within landfill leachate. The concentration of contaminants within leachate is dependent upon the waste type and will decline over time due to degradation of compounds, dilution by infiltrating water and losses to the vapour phase; therefore, existing leachate chemistry from other landfills was considered for this exercise. The environmental receptors considered are the groundwater body below the site within the bedrock and sand and silts for the List I substances, and an imaginary borehole immediately down-gradient of the site for the List II substances and non-listed substances.

Contaminants could reach the receptors via several pathways which comprise some different media components, transport mechanisms and attenuation processes:

Table 2. Pathways, transport and attenuation mechanisms

Media Component	Pollutant Transport Method	Attenuation Processes
HDPE Liner	Direct leakage through damage or defects or as a result of degradation of the liner	Declining source term. Dilution of leachate by rainwater infiltrating waste. Degradation of contaminants within leachate.
Mineral Liner (vertical pathway)	Advection and/ or Diffusion	Retardation, Dispersion
Inter-bedded clays, silts and sands (vertical pathway)	Advection and/ or Diffusion	Retardation, Dispersion
Aquifer Unit (Horizontal pathway/ saturated zone)	Advection and/ or Diffusion	Retardation, Dispersion

A QHRA has been undertaken using the following approaches:

- Analytical Solutions based on Domenico & Schwartz equation;
- A probabilistic method using Monte Carlo Simulations (LandSim);

Both advection and diffusion are possible contaminant migration mechanisms throughout the lifecycle of the landfill. The dominant mechanisms depend on the relationship between leachate levels and external hydraulic heads within the in situ inter-bedded clays, silts and sands and the underlying aquifer unit.

Domenico & Schwartz analytical solution has been used to predict concentrations of the priority contaminants (List I – Trichloroethene) at their respective compliance points, through the process of diffusion when leachate heads are below groundwater levels (winter watertable) in the surrounding subsoils – Scenario 1. A Conceptual Site Model and the landfill layout is presented in Fig. 4.

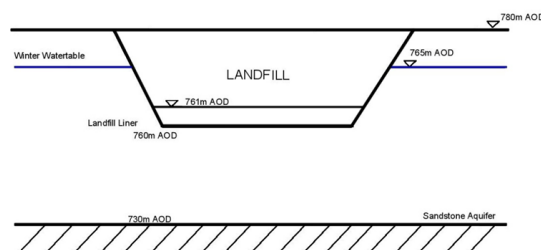


Fig. 4. Conceptual site model for Scenario 1 – winter watertable above leachate level

The input parameters used for the model are based on site-specific data when available and had been selected to be conservative. Domenico & Schwartz equation was used for the Scenario 1, and the solutions are derived in the Laplace Transform and was implemented into an Excel spreadsheet.

LandSim is used to predict leachate concentrations and elevations during the operational phase of the site and to estimate advective fluxes from the landfill when leachate heads exceed groundwater level (summer) in the surrounding inter-bedded subsoils and the potentiometric surface in the aquifer unit – Scenario 2 (engineered barrier without HDPE) and Scenario 3 (engineered barrier with HDPE) - Fig. 9.

Uncertainty within the selection of input parameters is addressed by the use of a probabilistic approach which allows the input parameters to be entered as ranges. The results are also returned as ranges and defined according to the probability of occurrence. The 95<sup>th</sup> percentile values are used as outputs from the model, which are representative of the reasonable worst-case performance of the landfill. The LandSim assessment models the performance of the landfill under normal conditions, i.e. it assumes that the engineering performance as designed throughout the operational life of the site.



## 5. Risk Assessment Results

The models predict the concentration of the priority contaminants at both the List I (TCE – trichloroethene) and List II (Ammonium) compliance points as appropriate.

The compliance point for List I substances is at the base of the vertical pathway.

The compliance point for List II substances is 100 m downgradient of the edge of the waste within the application boundary.

The 95<sup>th</sup> percentile (worst case) concentrations are reported for each of the modelled Scenarios. Scenario 2 & 3 and have been compared to the Guideline Concentrations.

The results for both analytical and probabilistic approaches are presented separately below:

### 5.1. Analytical Solutions - Scenario 1

For Trichloroethene (TCE), which is a List I organic contaminant, we have used an Excel spreadsheet which solves Domenico & Schwartz equation. The engineered barriers liner consisted of a 1 m of compacted clay and HDPE geomembrane.

Based on the chemical analysis of similar leachate, an initial concentration of TCE was considered in this analysis. The compliance point for the risk assessment is set at entry to watertable, which is, in this case, the external edge of the liner. Using EU/ Romanian Drinking Water Standards (Groundwater Directive), a target concentration for TCE should be set, which is  $10 \mu\text{g/l} = 1 \times 10^{-4} \text{mg/l}$ . Therefore, TCE concentration at any time should not exceed target values.

Evaluation of mass of TCE leaving the landfill is shown in Fig. 5a and concentration of TCE at compliance point in Fig. 5b – maximum concentration is  $2.46424 \times 10^{-5} \text{mg/l}$  which is lower than the target concentration of  $1 \times 10^{-4} \text{mg/l}$ . Therefore there is an acceptable risk.

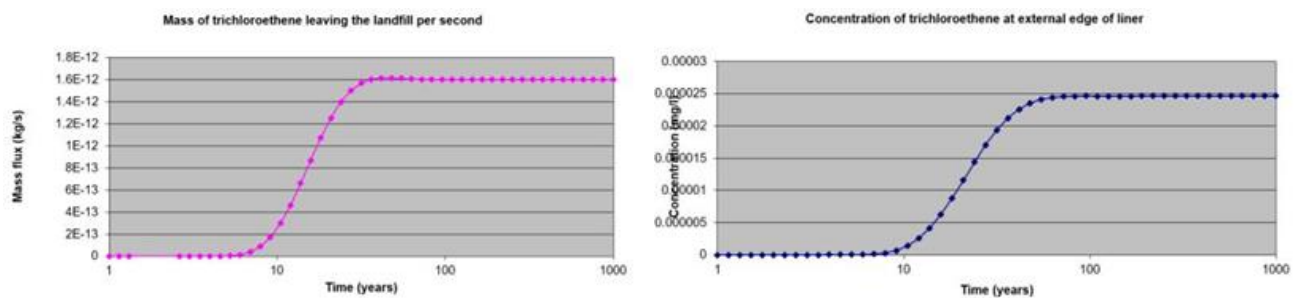


Fig. 5. (a) Scenario 1 – Mass of TCE leaving the landfill per second; (b) Scenario 1 – Concentration of TCE at the compliance point

### 5.2. Probabilistic Modelling - Scenario 2 & 3

To perform a probabilistic HRA, we have used LandSim software, a tool developed for UK Environment Agency by Golder. Both, Scenario 2 & 3 were modelled simultaneously in LandSim as Phase 1, respective Phase 2.

A graphic representation of the setup is presented in Fig. 6a. The results from the LandSim model are summarized in Fig. 6b – 7, for an ammonium concentration (List II substances) of 723 mg/l (LogTriangular distribution (4.37, 723, 3640) for which the trigger level is 0.5 mg/l.

From Fig. 6b – Scenario 2 for an engineered barrier without HDPE, it results that concentration at the external edge of the liner is higher than the trigger level and this value is halved at the compliance point but still higher than 0.5 mg/l.

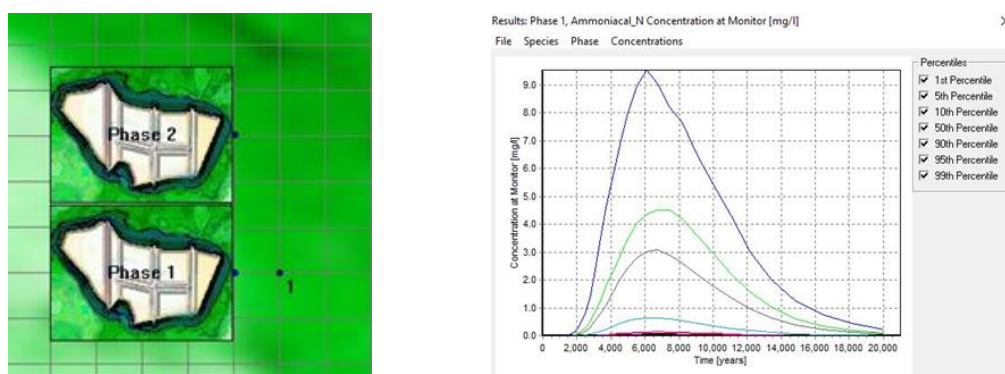


Fig. 6. (a) Scenario 2 (Phase 1) and Scenario 3 (Phase 2) for probabilistic risk assessment in LandSim; (b) Scenario 2 – Ammoniacal concentration at the external edge of the liner 95<sup>th</sup> percentile (light green curve)

On the other hand, Scenario 3 for an engineered barrier with HDOE, shows a value of 0.6 mg/l of Ammoniacal\_N which is slightly higher than the trigger value.

At the compliance point, the Ammoniacal\_N concentration should be lower than the EAL (Environmental Assessment Limit) due to retardation, biodegradation, diffusion, and dispersion.

As a conclusion, only an experienced barrier with HDPE will be compliant with Groundwater Directive requirements for the proposed landfill.

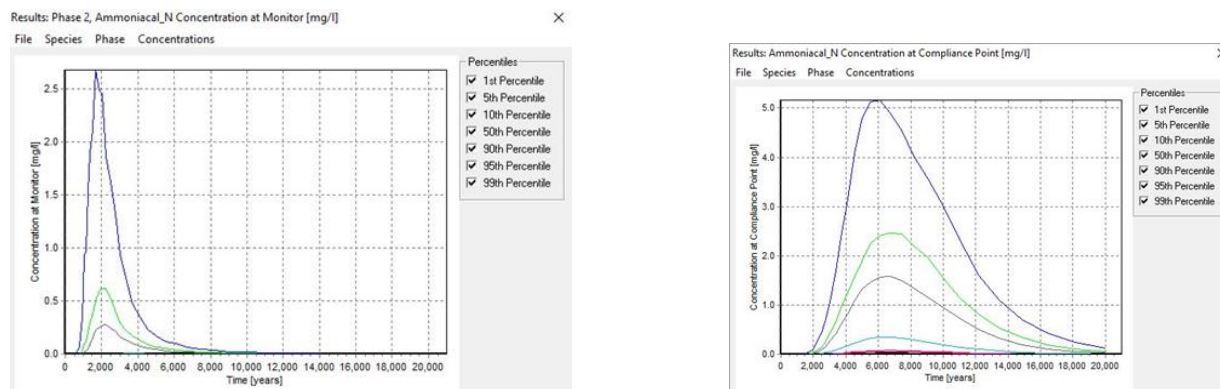


Fig. 7. (a) Scenario 3 – Ammoniacal concentration at the external edge of the liner 95<sup>th</sup> percentile (light green curve); (b) Scenario 2 & 3 – Ammoniacal concentration at compliance point 95<sup>th</sup> percentile (light green curve)

## 6. Conclusions

Due to the likely presence of substances from List I and II in the leachate, the VOC landfill has been engineered to include a leachate drainage and collection system as required by the Landfill Directive for non-hazardous landfills.

The results of the Risk Assessments show that List I substances in leachate are prevented from discharging directly to groundwater beneath the site. The results of the risk assessment for List II substances in leachate have shown that the landfill design prevents pollution of groundwater beneath the site from these substances for Scenario 3: Engineered Barrier with HDPE. Requisite surveillance in the form of risk-based leachate and groundwater monitoring will be carried out at the site, as part of Romanian Environmental Monitoring Plan.

Both conservative (analytical) and probabilistic risk assessments have shown that the landfill will not present a risk to groundwater and does not contravene the requirements of the Landfill/ Groundwater Directive.

## References

- Environment Agency, *Contaminated Fluxes form Hydraulic Containment Landfills – a review*, Science Report, SC0310/SR, (2004).
- Environment Agency, *Hydrogeological Risk Assessments for Landfills and the Derivation of Groundwater Control and Trigger Levels*, Report LFTGN01, (2003).
- Environment Agency, *Guidance on Assigning Values to Uncertain Parameters in Subsurface Contaminant Fate and Transport Modelling*, National Groundwater & Contaminated Land Centre Report NC/ 99/ 38/ 3, (2001).
- Pollard, S., Purchase, D., Herbert, S., *A Practical Guide to Environmental Risk Assessment for Waste Management Facilities*, Guidance Note 25 Version 2, Environment Agency, (2000).
- Golder Associate, *The Development of LandSim 2.5*, National Groundwater & Contaminated Land Centre Report GW/ 03/ 09, (2003).

## Risk-based remedial targets for contaminated land

Camelia Madear<sup>a\*</sup>, Gelu Madear<sup>b</sup>

<sup>a</sup>ECO-ROCCA Engineering SRL, 23, Parcului Street, Petritu - 335800, Romania

<sup>b</sup>GOLDER, 1, South Parade, Doncaster – DN1 2DY, UK

---

### Abstract

Land contamination describes a general spectrum of site and soil conditions and contains areas of high levels of chemical substances which occur naturally or in brownfield sites of industrial/ agricultural use. Also, land contamination may occur as a result of accidents, spillages, depositions, migrations or any other similar direct or indirect actions.

The paper presents a consistent methodology to derive remedial targets based on a human health risk assessment approach incorporating a source-pathway-receptor analysis. The methodology is based on RBCA – Risk-Based Corrective Action Procedure developed in the USA and adopted in UK/ EU and leads to the derivation of onsite remediation criteria, which is based on an assessment of the potential impact at the identified receptors.

*Keywords:* land contamination; soil condition; brownfield; human health; ecology; remedial targets, RBCA, CLEA.

---

### 1. Introduction

Whether there is new contamination which falls under Integrated Pollution, Prevention and Control Directive (Industrial Emission Directive 2010/75/EU) or past contamination exists, for any site owner, a series of questions must be answered:

- If the level of land contamination poses a threat to the environment (human health, ecology)?
- If yes, which are the actions that should be taken to remediate the land to an acceptable condition?

To decide if a certain level of contamination matters, the concentration and spatial distribution of any contaminants should be determined, and the risk posed to the environment evaluated.

The basic risk management process in dealing with the contaminated land has three main components:

1. Risk Assessment – if unacceptable risks exist, which actions should be taken;
2. Option Appraisal – evaluating feasible remediation strategies;
3. Implementation of the Remediation.

The overall risk assessment - RBCA methodology, is based on a tiered approach to determine risk-based remedial targets for soil and groundwater and includes initial site evaluation (conceptual site model), a detailed description of receptors, risk assessment for each considered receptor and appropriate overall remedial objective for the site.

Included is an example of developing a Conceptual Site Model for a Combined Sewer Overflow in the UK for a confidential client, during the investigation phase, to be used in the site characterisation process, and the corresponding human health risk assessment.

### 2. Project Description

Combined sewer overflow (CSO) chambers reduce the overcapacity at the treatment works. In this case, a new CSO chamber including screens and a small shaft tank was proposed to be constructed. It has been proposed to undertake the feasibility for an Unsatisfactory Intermittent Discharge (UID) Project in the West Midlands area, UK.

The works include the construction of a 7.6 m long CSO chamber with a depth of 2.36 m and a small 5 m diameter shaft tank, with a depth of 5 m and associated pipework and other structures. It is expected that the UID would act as a temporary storage facility for sewage, this being currently accommodated by an existing network of combined gravity sewers and manholes.

---

\* Corresponding author. Tel.: +40 744 60 77 38

E-mail address: camelia.madear@eco-rocca.ro

### **3. Environmental Settings**

#### *3.1. Site Location and General Description*

The site is situated approximately 8 km southwest of Birmingham City Centre. Approximately 600 m south of the site there is A45 Road, and the A4040 Road is mapped about 1.8 km northwest of the site. A few other minor roads serve the area and link to the site. The site is within a residential area.

#### *3.2. Hydrology*

The River Cole runs about 3 km northwest of the site and Westley Brook, one of the River Cole's tributary, flows approximately 150 m south of the site area. A few other smaller brooks are mapped near the site. The Grand Union Canal is approximately 2 km southwest of the site, and a few small ponds can be found nearby the site.

#### *3.3. Site Walkover*

A site walkover for the proposed scheme was carried out, and it showed that the site itself is in Sheldon – Birmingham, and the proposed works will be constructed on the road and pedestrian footpath. The access to the area is via urban roads from A45 – Coventry Road, including Barrows Lane, Church Road and Sheaf Lane. The site is covered by tarmac and is suitable for access by large vehicles. The site is adjacent to residential properties and is located on the relatively flat ground with the minimal ground slope. Also, services have been identified on site.

### **4. Geology and Hydrogeology**

#### *4.1. Geology*

Topsoil - is expected to be encountered in areas of undisturbed ground. According to BGS Borehole Records, the Topsoil thickness in the area ranges between 0.15 m and 0.65 m and mainly consists of loose brown clayey sand with frequent rootlets, loose dark brown clayey sand with a little gravel and many rootlets and black sandy clay with frequent rootlets.

Made Ground - No areas of Made Ground are shown on the geological map. However, it is likely to be encountered due to the historical activities at the site. Made Ground is expected to be associated with road construction and site preparation for nearby structures and buildings. Composition and thickness are likely to be varied, and contaminated materials may be present. The studied historical boreholes provided by BGS do not show any Made Ground.

Alluvium - identified on the map about 100 m southwest and about 200 m northwest of the site. In the urban areas, the Alluvium is largely obscured by Made Ground commonly associated with the construction of flood defences, landscaping and the diversion of the rivers and streams into man-made culverts. Consequently, the natural boundaries of the Alluvium in much of the urban area cannot be traced. The Alluvium typically comprises an upper layer of brown clay or silt, up to about 3 m thick, underlain by several metres of pebbly sand and gravel. Thin lenses of peat may be present.

First River Terrace Deposits - are identified on the map approximately 100 m north, east and south of the site. It is commonly 1 to 2 m thick, though exceptionally it reaches 7.8 m thick in some areas. The lithology is predominantly composed of massive-bedded, and cross-bedded gravel and pebbly sand with well-rounded pebbles of Triassic-derived quartz and quartzite.

Glaciofluvial Deposits - are present, at the surface, in the vicinity of the site. These deposits commonly consist of poorly sorted, red, orange and yellow sand, clayey sand, pebbly sand and gravel. Sand and Gravel is generally orange-red, red-brown or yellow, and ranges from poorly to well graded.

Mercia Mudstone Group - represents the solid geology and is likely to be present below the Glaciofluvial Deposits at the site. The Group consists predominantly of red to reddish brown mudstone with sparse grey-green beds. The upper part of the Mudstone is likely to be weathered to clay. The studied historical boreholes provided by BGS do not show any Mercia Mudstone.

#### *4.2. Hydrogeology*

Surface Waters - The site is near several brooks, which may contribute to water levels on site.

Groundwater - The Glaciofluvial Deposits are classified as a Minor Aquifer (variable permeability), and these can be fractured or potentially fractured rocks, which do not have high primary permeability or other formations of variable permeability including unconsolidated deposits. Although not producing large quantities of water abstraction, they are essential for local supplies and in supplying base flow to rivers. Regarding the soil classification in the area, soils of high leaching potential are likely to be encountered. The underlying Mercia Mudstone is classified as a "Non-Aquifer". According to the Environment Agency website, the site is not within a Groundwater Source Protection Zone.

## 5. Historical Land Use

Table 1. Evidence of the historical land use

Map Year of First Occurrence	Notable Features	Potential Contamination Sources
1888 - 1905	The maps show that the area around the site is predominantly rural with some settlements here and there, including farms and cottages. Approximately 250 m northeast of the site there is a Smithy. A Fish Pond and a Gravel Pit can be seen about 850 m west of the site. Another Fish Pond is mapped next to Sewage Pump, which is located about 1.5 km northwest of the site.	On-site: The Road Off-site: Smithy, Gravel Pit, Sewage Pump, Brick Works, Tank, Old Marl Pits
1916 - 1938	Housing and roads development can be observed around the site since 1905. A few new features have sprung up around the site area. Approximately 600 m northeast of the site there are mapped and Old Sand Pit and a Sewage Pump. A Spring is mapped about 250 m northwest of the site.	On-site: The Road Off-site: Smithy, Gravel Pit, Sewage Pump, Brick Works, Tank, Old Marl Pits, Old Sand Pits, Gravel Pit
1954 - 1969	More housing and roads expansions can be noticed around the site area. Approximately 150 m northwest of the site there is mapped a Spring, a Well and Sinks. A Timber Yard is present approximately 300 m northeast of the site and these later become works. Also, the Smithy, the Sewage Pump and the Tanks are no longer mentioned on these recent maps.	On-site: The Road Off-site: Smithy, Gravel Pit, Sewage Pump, Brick Works, Tank, Old Marl Pits, Old Sand Pits, Gravel Pit, Model Railway Ground, Timber Yard (later Works)
1970 - 1978	Westley Brook, which runs southwest to northeast direction, is mapped about 150 m south of the site. Areas around the site have seen rapid infrastructural developments such as new houses, roads and other community amenities.	On-site: The Road Off-site: Smithy, Gravel Pit, Sewage Pump, Brick Works, Tank, Old Marl Pits, Old Sand Pits, Gravel Pit, Model Railway Ground, Timber Yard (later Works)
1980 - 1999	No significant changes are noticed from the previous maps. The Works had been redeveloped as housing by this date.	On-site: The Road Off-site: Smithy, Gravel Pit, Sewage Pump, Brick Works, Tank, Old Marl Pits, Old Sand Pits, Gravel Pit, Model Railway Ground, Timber Yard (later Works)

## 6. Conceptual Site Model and Hazard Assessment

The primary regulatory regime under which contaminated land is managed in the UK is Part IIA of the Environmental Protection Act (EPA) 1995. The strategy for the assessment of potential land contamination is based on current guidance documents related to Part IIA of the EPA with particular reference to DEFRA's Contaminated Land Reports CLR11, CIRIA Reports C552 and BS10175:2011. As stated in CLR11, a key element of the Preliminary Risk Assessment is the development of a conceptual site model CSM, which may be refined or revised as more information and understanding is obtained through the risk assessment process.

The CSM is described regarding the contaminant Source, transport Pathways and possible Receptors that may be present, and the potential Pollutant Linkages between them, as defined in the relevant legislation and guidance.

### 6.1. Potential Source of Contamination

Some potential on-site and off-site sources of contamination have been identified and are summarised below:

On-site: Source 1 (S1) - Road & Associated Made Ground: The Road is located on site and is a potential source of contamination of fuel and oil spillage, and the Made Ground is associated with the construction of the road.

Off-site: Source 2 (S2) - Timber Yard: While having the potential to give rise to contaminants and located on the Terrace Deposits it is a sufficient distance and therefore unlikely to have a significant impact on the proposed works. The ground investigation should include appropriate tests.

Off-site: Source 3 (S3) - Cleaning Services: Close to the site and localised on Glaciofluvial Deposits to the north of a former stream, has the potential to have given rise to contamination such as solvents in the groundwater. The ground investigation should include appropriate tests on groundwater.

As a result of characterising the potential sources identified that could reasonably be linked to the site, the Road, the Timber Yard and the Cleaning Services are considered to be potential sources that can affect the site.

## 6.2. Potential Pathways

The potential pathways by which receptors might be exposed to contaminants (sources) at the site can vary depending on the proposed or current land use as follows:

For humans, the three possible routes of exposure to contaminants are: inhalation of dusts or gas – Pathway 1 (P1); ingestion of dusts or soil either by hand-to-mouth activity or by eating plants grown in contaminated soils - Pathway 2 (P2); dermal (skin) contact with contaminated soils and waters and transfer of contaminants through the skin into the body - Pathway 3 (P3);

For plants and landscaped areas, the main pathway for exposure involves either direct contact with contaminated soils, ground gas or groundwater or uptake of contaminants into the plant leading to adverse impact - Pathway 4 (P4) & Pathway 9 (P9);

For buildings, property and services, the main pathways by which buildings can be affected are through soil gas pooling within the structures, by contact with aggressive or acidic soils or service trenches acting as preferential migration pathways - Pathway 7 (P7);

For controlled waters, the primary routes by which these can be affected are: run-off from the site surface entering surface watercourses near the site - Pathway 5 (P5); leaching of contaminants from the soil migrating vertically or laterally to groundwater beneath the site - Pathway 6 (P6); movement of dissolved contaminants in soil pore water - Pathway 6 (P6); movement of contaminants via groundwater to surface water bodies - Pathway 6 (P6).

## 6.3. Potential Receptors

Potential receptors at this site, related to the development proposals, the current use of the site, its location relative to sensitive environmental receptors and the ground and groundwater conditions are as follows:

Human Receptors associated with the proposed development are the occupants of adjacent properties, construction workers, public during construction, maintenance workers – Receptor 1 (R1).

The property receptors associated with the proposed development are adjacent buildings and on-site services – Receptor 2 (R2).

Ecological receptors reflect that the area is within a Countryside Stewardship Scheme Target Area and also, the following ecological features are mapped around the site of interest: Green Belt is mapped about 150 m south of the site; National Forest is mapped about 600 m southwest of the site and Woodland Grant Schemes are mapped about 450 m southwest of the site - Receptor 3 (R3).

The controlled waters receptors associated with the proposed development are: surface waters adjacent to the site and groundwaters - Receptor 4 (R4) and reflect in leaching or dissolution of contaminants in soil and subsequent migration of contaminants in groundwater, lateral migration of contaminated groundwater and lateral migration of dissolved phase contaminants via preferential pathways such as drains, pipes, boreholes and trenches.

Based upon the potentially active Sources/ Hazards, Pathways and Receptors, a Conceptual Site Model has been derived (Fig. 1), including the potential pollutant linkages (Fig. 2).

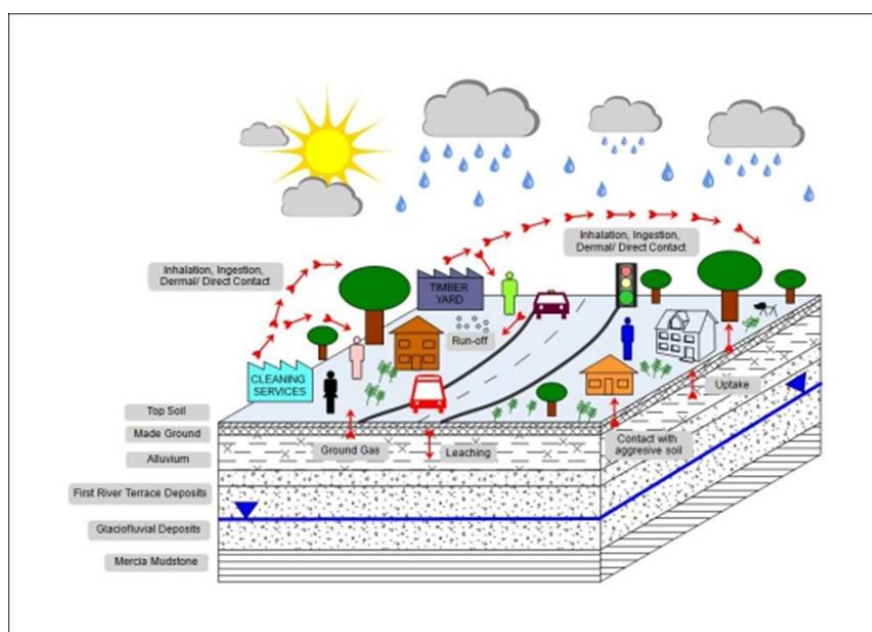


Fig. 1. Conceptual site model



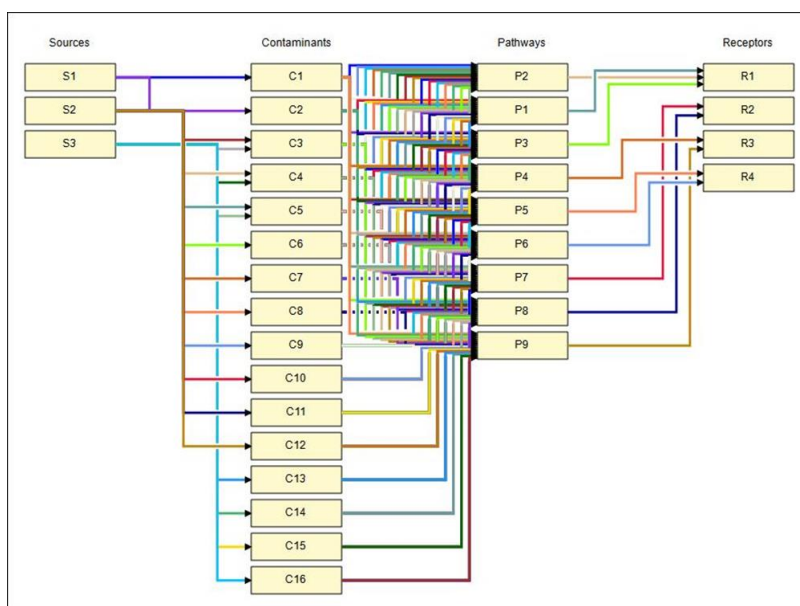


Fig. 2. Network representing S-P-R linkages

## 7. Human Health Risk Assessment Based on RBCA/ CLEA

Environmental remediation of contaminated sites is based on a risk-based approach for the definition of remedial targets, where the actual pollution of the site is evaluated depending on the effective risk posed to the human health of exposed receptors. The most used technical and scientific references for this approach are the ASTM Risk-Based Corrective Action (RBCA) standards for evaluating petroleum and chemical release at sites. Both standards provide guidance for the development of a Risk-Based Corrective Action program that integrates the sciences of ecological and human-health risk-based decision making into the corrective action process. More details are found in ASTM E1739-95 (ASTM, 1995) and E2081-00 (ASTM, 2000) standards, which have been issued by ASTM Committee E50 on Environmental Assessment.

The RBCA processes use a tiered approach which incorporates site assessment and response actions with human health and ecological risk assessment, in order to determine the need for remedial actions and to tailor corrective action activities to site-specific conditions and risks. In order to use this tiered approach, an intrusive site investigation is required, which will provide information for the evaluation of the potential effects on the human health receptors; therefore assessing if the site requires remedial action. Based on the derived CSM, an intrusive geo-environmental site investigation plan has been devised, and a sampling & laboratory analysis schedule has been sent to site investigation contractor.

For this paper, we present only the relevant chemical tests required for the Soil Tests – Human Health and Ecology:

Suite B: Soil Tests: Arsenic, Cadmium, Chromium-Total, Lead, Mercury, Zinc, Copper, Nickel, Sulphur-total, Cyanide-total, Sulphide, Sulphate-total, Nitrate – Nitrogen, Ammoniacal Nitrogen, pH, Asbestos (screening & identification MDHS 77), Semi-Volatile Organic compounds (USEPA 8270 including Phenol and Polycyclic Aromatic Hydrocarbons), Volatile Organic Compounds (USEPA 8260), Total Petroleum Hydrocarbons (C10-C40), Petroleum Range Organics (C3 – C8), PCBs (7 congeners).

The RBCA tiered approach has been adopted in the UK by the Environment Agency and transposed in Contaminated Land Report 11 - Model Procedures for the Management of Land Contamination [Environment Agency, 2004]

UK Environment Agency developed a tool for Contaminated Land Exposure Assessment which is used in the UK for Human Health Risk Assessment and the derivation of the risk-based remedial targets for contaminated land (EA, 2009a, EA 2009b). The CLEA model uses generic assumptions about the fate and transport of chemicals in the environment, and a generic conceptual model for site conditions and human behaviour, to estimate child and adult exposure to soil contaminants for those living, working, and/ or playing on contaminated sites over long time periods.

Soil Guideline Values (SGVs) are derived using the CLEA model by comparing the estimated exposure with Health Criteria Values (HCVs) that represent a tolerable or minimal risk to health from chronic exposure. The derivation of HCVs is performed using toxicological data. Soil Guidance Value is a screening tool for the Generic Quantitative Risk Assessment of Land Contamination and represents “trigger values” – above this level, soil concentrations may pose a possibility of significant harm to human health.

We have used CLEA Model running in backward mode, to derive Risk-Based Remedial Targets or Assessment Criteria for our site, starting with a prescribed level of exposure (equal to HCV), and determining the soil concentration that might give rise to that level of exposure.



The following contaminants were taken into consideration, for which laboratory analysis are available: Arsenic: 13 mg/ kg and Mercury: 0.25 mg/ kg. Using the generic residential land use scenario for semi-detached houses and a generic female receptor for all age classes (1 – 18) and an exposure duration of 75 years, we have obtained the following values for SGVs or Remedial Targets: Arsenic: oral: 166 mg/ kg & inhalation: 363 mg/ kg and Mercury: inhalation: 4.97 mg/ kg.

## **8. Conclusions**

Considering few exposure pathways: direct soil and dust ingestion, dermal contact with indoor dust, dermal contact with soil, inhalation of indoor dust, inhalation of soil dust, inhalation of indoor vapor, inhalation of outdoor vapor, and taking into account that measured media concentration for Arsenic and Mercury are lower than Target Values, no remedial actions are required.

Compared to “trigger values” for Romanian Contaminated Land Standards according to OMAPPM Nr. 756/ 1997: Arsenic = 15 mg/ kg for “sensible land” and Arsenic = 25 mg/ kg for “less sensible land”; Mercury = 1 mg/ kg for “sensible land” and Mercury = 4 mg/ kg for “less sensible land”, we note that Target Values for Arsenic are much higher (166 mg/ kg > 15 mg/ kg), whereas for Mercury are comparable (4.97 mg/ kg > 1 mg/ kg)

## **References**

- ASTM, *Standard Guide for Risk-Based Corrective Action Applied at Petroleum Release Sites*, ASTM, West Conshohocken, PA 1995, E 1739-95 (Re-approved 2002).
- ASTM, *Standard Guide for Risk-Based Corrective Action*, ASTM, West Conshohocken, PA, 2000, E 2081-00.
- Environment Agency, *Updated Technical Background to the CLEA Model*, Science Report: SC050021/ SR3, (2009a).
- Environment Agency, *CLEA Software (Version 1.05) Handbook*, Science Report: SC050021/ SR4, (2009b).
- Environment Agency, *Land Contamination Risk Assessment Tools – An Evaluation of Some of the Commonly Used Methods*. R&D Technical Report P260, (2000).
- Environment Agency, *Model Procedures for the Management of Land Contamination*, Contaminated Land Report 11, (2004).
- U.S. EPA, *Risk Assessment Guidance for Superfund, Vol. 1, Human Health Evaluation Manual, Part A*, EPA/ 540/ 1-89/002, 1989.

## Construction quality assurance and quality control at landfills

Camelia Madear<sup>a\*</sup>, Gelu Madear<sup>b</sup>, Sorin Mihai Radu<sup>c</sup>

<sup>a</sup>ECO-ROCCA Engineering SRL, 23, Parcului Street, Petrila - 335800, Romania

<sup>b</sup>GOLDER, 1, South Parade, Doncaster – DN1 2DY, UK

<sup>c</sup>University of Petrosani, 20, University Street - 332006, Petrosani, Romania

---

### Abstract

In order to achieve the required quality parameters for the impermeable barrier of a Municipal Solid Waste Landfill, the construction process should follow proper procedures. There are two main areas of Quality Assurance and Quality Control (QA/QC) process which should be performed during the construction phase of the MSW Landfill: Construction of compacted clay liners & Geosynthetic material procurement and installation. The paper presents the international approach in the QA/QC process for MSW Landfills comparative with Romanian Legislation and Practice. The importance of the Construction Quality Assurance (CQA) process at the installation of the geomembrane for an imaginary landfill is emphasized by a comparison study on the performance of the landfill with and without CQA.

*Keywords:* landfills; quality assurance; quality control.

---

### 1. Introduction

Construction Quality Assurance (CQA) and Construction Quality Control (CQC) are significant factors in the overall landfill quality management, and the Manufacturing Quality Assurance (MQA) and Manufacturing Quality Control (MQC) of the geosynthetic materials (i.e. geomembranes, geotextiles, geonets, geogrids, geosynthetic clay liners etc.) are equally important.

It is imperative to understand which is the difference between MQC and MQA, and between CQC and CQA.

Construction Quality Assurance (CQA) is a planned system of activities that provide the owner and the regulatory body the assurance that the landfill was constructed as specified in the design. Several activities are included in the CQA: inspections, verifications, audits, evaluations of materials and execution, which are necessary to determine and document the quality of a landfill.

Construction Quality Control (CQC) is a planned system of inspections that are used to monitor and control the quality of a landfill. CQC is performed even by the installer (in case of geosynthetics installation), or by the contractor (in case of natural soil materials), and is necessary to achieve quality in the constructed or installed system. CQC refers to all the measures taken by the installer/ contractor to determine compliance with the requirements for materials and execution as stated in the plans and specifications for the project.

Manufacturing Quality Control (MQC) is a planned system of inspections that are used to monitor and control directly the material which was factory manufactured and is usually performed by the manufacturer of materials. MQC also refers to all the measures that were taken by the manufacturer to determine compliance with the requirements for materials and execution.

Manufacturing Quality Assurance (MQA) is a planned system of activities that assure that all the materials were constructed as stated in the certification documents. Several activities are included in the MQA: inspections, verifications, audits and evaluation of the raw materials and geosynthetic products in order to assess the quality of the manufactured materials. MQA also refers to all the measures that were taken by the Manufacturing Quality Assurance organisation to determine if the manufacturer complies with the product certification.

Manufacturing Quality Assurance and Construction Quality Assurance are performed independently from Manufacturing Quality Control and Construction Quality Control. Even though MQA/ CQA and MQC/ CQC are distinct activities, they have similar objectives, and the processes will complement one another.

---

\* Corresponding author. Tel.: +40 744 60 77 38  
E-mail address: camelia.madear@eco-rocca.ro

On the other hand, an effective MQA/CQA program can lead to the identification of deficiencies in the MQC/ CQC process, but the Manufacturing Quality Assurance and Construction Quality Assurance program by itself (in the complete absence of MQC/ CQC program) would lead to an unacceptable level of quality.

Having an effective MQC/ CQC and MQA/ CQA plans in place would provide the required quality management for landfills.

## 2. QA/QC Process for Compacted Clay Liner Construction

Adequate QA/QC process directly impacts the permeability of compacted clay liners. In this process there are several stages which control the final quality of the compacted clay liner:

- QA/QC before and during clay liner construction;
- Presence of qualified QA/QC personnel on site;
- Preparation and filing of a documentation report.

The construction quality assurance and quality control processes for soil liners have to fulfil three main goals:

1. Sustainability of clay liner materials;
2. Adequate placement and compaction of liner materials;
3. Protection of compacted clay liner.

The steps required to accomplish these three objectives are summarised as follows:

- Adequate preparation of the subgrade;
- Clay liner materials should be suitable and conform to CQA plan and specifications;
- Clay liner material should be prepared, if required, by controlling the moisture content or granulometry;
- Clay should be placed in layers of specific thickness and adequately compacted;
- Protection from damages caused by desiccation/ freezing of the compacted clay liner;
- Preparation of the final surface to install the geomembrane.

A typical testing program in the USA for construction quality control would comprise the followings (as presented by Qian et al.):

Table 1. Testing program for construction of compacted clay liners

Facility Component	Factor	Test Method
Clay Borrow Source	Unified Soil Classification	ASTM D2487
	Moisture-Density Curve	ASTM D1557
	Moisture/ Density/ Permeability Relationship	ASTM D1557
		ASTM D5084
Compacted Subgrade	Moisture/ Density (Nuclear)	ASTM D2922
Clay Liners	Moisture/ Density (Nuclear)	ASTM D2922
	In-situ Permeability Testing	ASTM D5084
	Thickness	Surveying or direct measure
	Slope	Surveying

A typical CQA testing program in the UK during the construction phase of a liner is presented in Environment Agency, and it is based on Eurocode 7, British Standard BS1377 and BS5930.

Romanian legislation regarding the quality control in construction, which also applies to landfills, consists of Law 10/ 1995 and a series of Regulations. Also, there are some Technical Guides and Standards to be used for testing and controlling the compacted clay liners: Technical Guide for Landfilling GT 067-2014, GE-026-97, P 134-95, GP 129-2014.

The Technical Guide for Landfilling requires explicitly at paragraph 3.1.6.2 that a field trial of the compacted clay liner should take place, before the landfill construction. Annexe 1 of the same guide specifies precisely how the field trial should be performed and it is represented in Fig. 1.

Proper documentation of all construction items is essential. The location of any test must be clearly indicated. The drawings and narrative should be clear and concise, and a daily log of construction activities and quality assurance and quality control tests should be maintained.

Finally, a detailed construction certification report should be prepared by both the design and quality assurance firms for submission to Environment Agency.

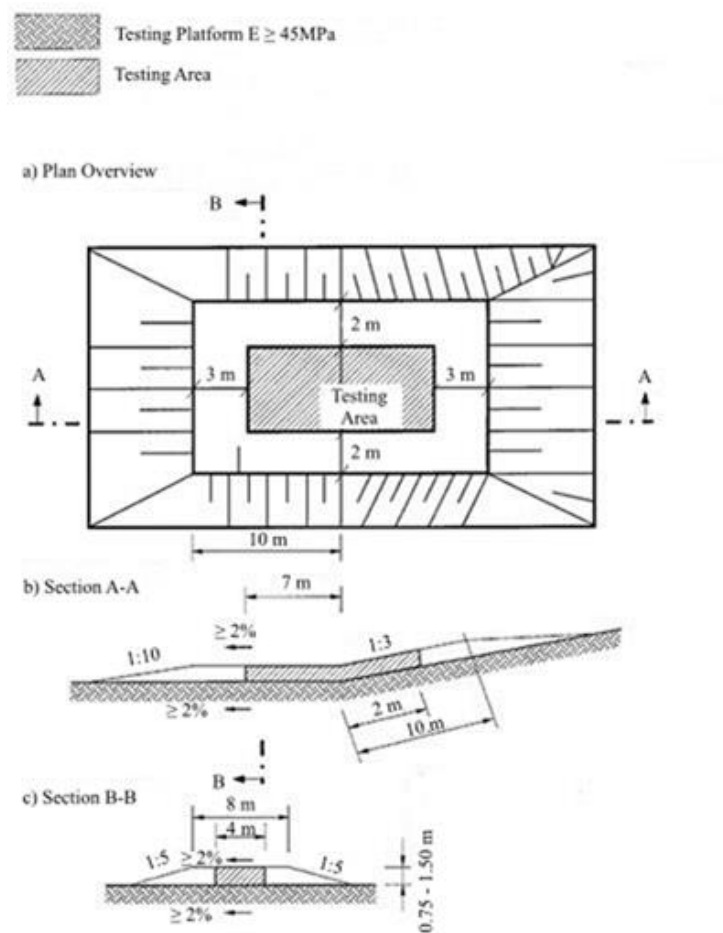


Fig. 1. Compacted clay liner field trials according to Romanian regulations

### 3. QA/QC Process for Geomembranes Installation

Geosynthetic material installation includes the placement and attachment of the following components into an MSW Landfill: geomembranes, geonets, geotextiles, geocomposites, geosynthetic clay liners, and occasionally, geogrids.

Proper QA/QC must be provided during geosynthetic material installation. QA is provided by an organisation separate from production and installation, whereas QC is provided by the manufacturers and installers of the various components of the geosynthetic system.

In this regard, geosynthetic materials have four levels of quality management associated with them:

- Manufacturing Quality Control – MQC;
- Manufacturing Quality Assurance – MQA;
- Construction Quality Control – CQC;
- Construction Quality Assurance – CQA.

It is important to highlight that a Construction Quality Assurance (CQA) representative should be present on site for material delivery and unload and ensure that conformance test samples are obtained and sent to a laboratory for testing.

For geomembranes, the following conformance tests should be conducted:

- Thickness: ASTM D5199;
- Tensile strength and elongation: ASTM D638, ASTM D882, ASTM D751;
- Puncture: D4833;
- Tear resistance: ASTM D1004;
- Ply adhesion: ASTM D413;
- Density: ASTM D1505 or ASTM D792.

Romanian guidelines on testing and installation of geomembranes are presented in NP 075/ 2002 and GP 107-04, and in the following standards:

- SR EN 13265: 2003;
- SR EN 13257: 2001;
- SR EN 13252: 2001;
- SR EN 13253: 2001;
- SR EN 13251: 2001.

The CQA engineers should review all conformance test results from laboratory conformance testing and report any non-conformance, and ensure that test results meet or exceed the values listed in the CQA plan.

Installation of geomembrane is relatively complicated, and the field seaming is an essential step of the successful functioning of the geomembrane as a barrier to liquid flow.

The CQA inspector/ monitor must ensure that the personnel performing field seaming is fully qualified. Welding technicians should conduct trial welds, and seam test performed accordingly. As each panel is deployed, the geomembrane surface should be observed by CQA monitor for any defects, any holes, blisters, undispersed raw materials, and any sign of contamination. Each location suspected of having defects must be non destructively tested in the presence of the CQA monitor.

The CQA monitor should record daily documentation of all non-destructive and destructive tests.

Romanian Guidelines for the installation of geomembranes at landfills is presented in Chapter 10 of GB 107-04, and the seam testing should be performed in accordance with paragraph 4.5 of NP 075/ 2002.

In order to emphasise the importance of having a CQA plan and QA/QC personnel on site – CQA engineer/ inspector/ monitor, we performed a LandSim analysis for an imaginary landfill, with and without CQA monitoring (liner installed under CQA or NOT installed under CQA).

Table 2 presents the representative input data for LandSim analysis, with the difference of defects between the two runs.

Table 2. LandSim input parameters for liner installed under CQA (with CQA) and liner NOT installed under CQA (without CQA)

Parameter of liner	With CQA	Without CQA
Design thickness of clay (m)	SINGLE (1)	SINGLE (1)
Pathway moisture content (fraction)	UNIFORM (0.35, 0.4)	UNIFORM (0.35, 0.4)
Onset of FML* degradation (years since filling commenced)	150	150
Pathway longitudinal dispersivity (m)	SINGLE (0.1)	SINGLE (0.1)
Time for area of defects to double (years)	100	100
Membrane defects** (number/ ha)		
Pin holes	Min. 0, Max. 25	Min. 0, Max. 750
Holes	Min. 0, Max. 5	Min. 0, Max 150
Tears	Min. 0, Most likely 0.1, Max. 2	Min. 0, Most likely 0.5, Max 10
Hydraulic conductivity of mineral lower liner (m/s)	LOGTRIANGULAR (1e-11, 5e-11, 5e-10)	LOGTRIANGULAR (1e-11, 5e-11, 5e-10)

\*Flexible Membrane Liner

\*\*The most likely value for the PDFs which represents the density of pin holes and holes will move from the minimum value selected above to the maximum value selected above over the time period before FML degradation commences.

A comparison of the two runs is presented in Fig. 2 – 5. On the left, we have a concentration of the Ammoniacal \_N for the installed liner under CQA, at the base of the clay liner, at the monitoring point, and finally at the compliance point, whereas on the right side, we have the same results for the liner to install under CQA.

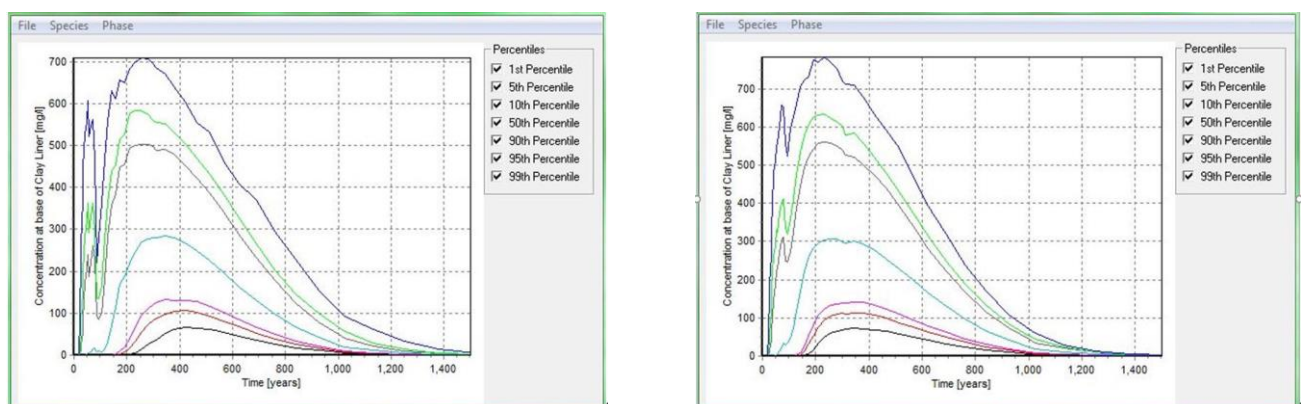


Fig. 2. (a) Concentration at base of clay liner (mg/l) – with CQA; (b) Concentration at base of clay liner (mg/l) – without CQA

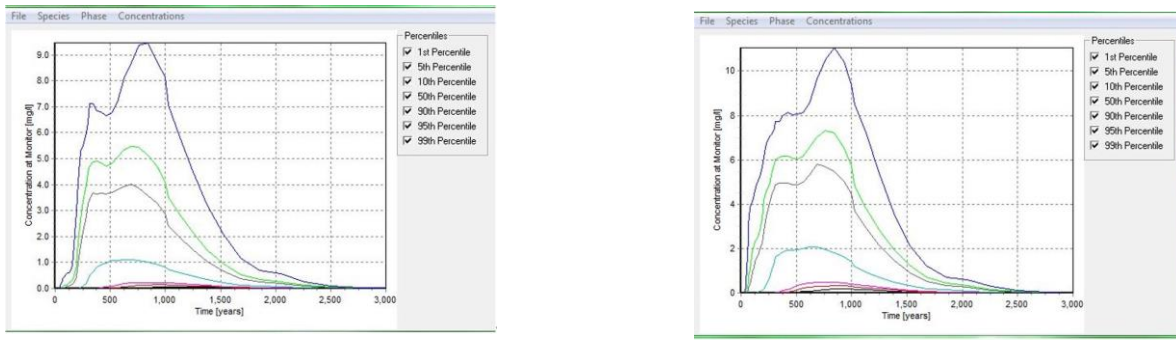


Fig. 3. (a) Concentration at monitor (mg/l) – with CQA; (b) Concentration at monitor (mg/l) – without CQA

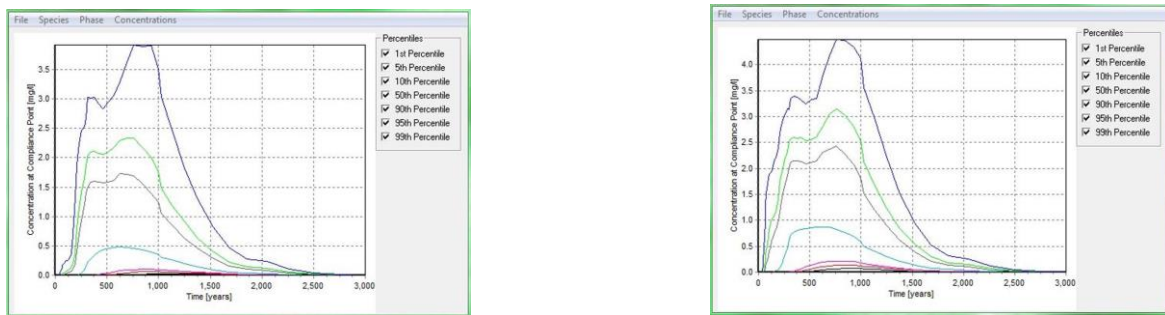


Fig. 4. (a) Concentration at compliance point (mg/l) – with CQA; (b) Concentration at compliance point (mg/l) – without CQA

Statistics at the compliance point is summarised in Fig. 5 (a) and Fig. 5 (b). Comparing the mean value of the concentration of Ammoniacal\_N for the first 300 years, it results that without a CQA plan in place, the concentration mentioned above, doubles at the compliance point, making the engineered barrier being unsuitable for the protection of groundwaters in accordance with Romanian Drinking Water Standards.

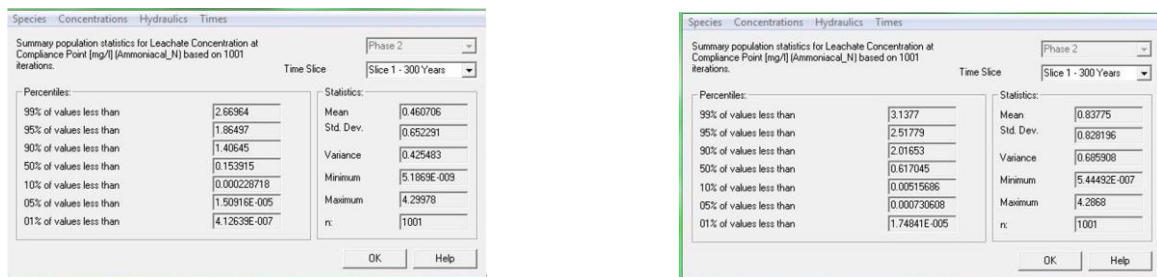


Fig. 5. (a) Summary Statistics at compliance point (mg/l) – with CQA; (b) Summary Statistics at compliance point (mg/l) – without CQA

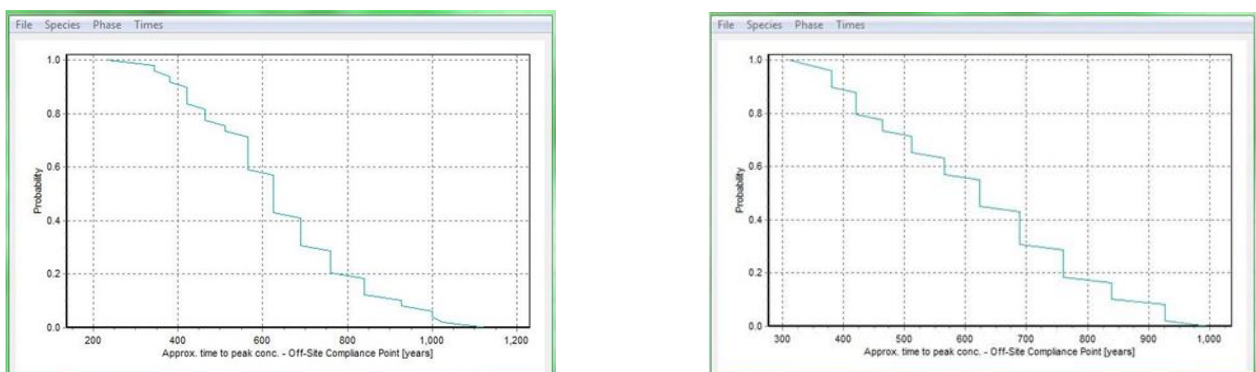


Fig. 6. (a) Time to peak concentration at compliance point with CQA; (b) Time to peak concentration at compliance point without CQA

Fig. 6 (a) represents the time to peak concentration for Ammoniacal\_N for the case with Construction Quality Assurance (CQA) at an off-site compliance point with its maximum probability after approximative 200 years, whereas Fig. 6 (b) represents the time to peak concentration for Ammoniacal\_N for the case without Construction Quality Assurance (CQA) at an off-site compliance point with its maximum probability after approximative 300 years.

This comparison shows the importance of the implementation of the CQA plan - although we might have a good design of the engineered barrier.

#### **4. Conclusions**

Due to the fact that landfills contain massive amounts of organic materials and hold a huge potential to pollute the groundwater and also because the landfill baseliners are by nature buried once these are constructed, and the opportunity to do repairs is extremely limited, a proper Construction Quality Assurance and Construction Quality Control is paramount for the sake of any landfill. Therefore, construction QA/QC at landfills is an essential process in order to achieve the required parameters for the engineered barrier of a landfill. Each construction phase of the impermeable barrier, namely the compacted clay liner and the installation of the geomembrane has its own specific QA/QC procedures.

The importance of the CQA plan is emphasized in this paper and thus the existence of the qualified quality assurance firms (Third-Party Inspectors) which implement the CQA plan and certify to the regulatory bodies (i.e. Environment Agency) that everything is in accordance with the required standards, is paramount for meeting the CQA objectives.

#### **References**

- Ghid privind proiectarea depozitelor de deseuri cu materiale geosinetice*, GP 107-04.
- Normativ tehnic privind depozitarea desurilor*, MMGA 2004.
- Legea 10/1995 – privind calitatea in constructii*.
- Normativul pentru utilizarea materialelor geosintetice la lucrarile de constructii*, NP 075/ 2002.
- Qian, X., Koerner, R.M., Gray, D.H., *Geotechnical aspects of landfill design and construction*, Prentice Hall, (2002).
- Environment Agency, LFE4 – *Earthworks in landfill engineering. Design, construction and quality assurance of earthworks in landfill engineering*.
- Ghid privind controlul lucrarilor de compactare a pamanturilor necoezive*, GT 067-2014.
- Ghid pentru executia compactarii in plan orizontal si inclinat a terasamentelor*, GE-026-97.
- Ghid practic pentru proiectarea lucrarilor ce inglobeaza materiale geosintetice*, P 134-95.
- Ghid privind proiectarea geotehnica*, GP 129-2014.



# Design of leachate collection system using Monte Carlo simulation

Camelia Madear<sup>a\*</sup>, Gelu Madear<sup>b</sup>

<sup>a</sup>ECO-ROCCA Engineering SRL, 23, Parcului Street, Petrila - 335800, Romania

<sup>b</sup>GOLDER, 1, South Parade, Doncaster – DN1 2DY, UK

---

## Abstract

All landfills must have at their base a leachate drainage layer consisting of sands and gravels and/ or geosynthetic drainage material. The most important requirement for a Municipal Solid Waste (MSW) Landfill is that the leachate collection system has adequate drainage capacity to handle the maximum leachate flow produced during landfill operations. The authors present in the paper a comparison of few calculation methods for the design of leachate collection systems using a probabilistic approach, so these systems are compliant with the current legislation.

*Keywords:* leachate, landfills; drainage layer; probabilistic approach; Monte Carlo simulation.

---

## 1. Introduction

The leachate drainage layer has a minimum thickness of 0.5 m as the Landfill Directive stipulates it (1999/31/EC); moreover, the leachate head builds up must be less than this thickness. To properly design a leachate drainage system for a landfill liner, we must be able to estimate the maximum saturated depth over the barrier for any proposed configuration. Landfill Directive, as well as National Regulations, limit the maximum leachate head over the liner to 0.5 m for MSW Landfills.

Factors affecting this maximum saturated depth include the inflow rate into the drainage layer, the hydraulic conductivity of the leachate drainage layer, the leachate flow distance from the upstream boundary to the leachate collection pipe, the slope of the landfill bottom liner, and the hydraulic condition at the downstream end of the drainage layer. Calculation of the liquid head over the barriers is based on the maximum inflow rate using a steady-state assumption, making the design conservative.

Few methods are currently used to calculate the maximum leachate head over the landfill liner, two of them proposed by Moore and two by Giroud et al. and McEnroe, respectively. To take into account the variability of inflow rate, hydraulic conductivity and horizontal drainage distance between the drainage pipes, to the maximum liquid head over the barrier, we have used Monte Carlo simulations using @RISK software. Input parameters are described by Probability Density Functions (PDFs) instead of unique values – as used in a deterministic design.

## 2. Probability Distribution Functions for Input Parameters

Parameters which affect the maximum leachate head present in the drainage layer are:

- Horizontal drainage distance,  $L$ ;
- Leachate inflow rate,  $r$ ;
- Hydraulic conductivity of the drainage layer,  $k$ ;
- Slope angle of the drainage layer,  $\alpha$ .

To run a stochastic analysis, first, we have to define these parameters as distribution functions.

Based on international practice, experience and regulations, the following distributions were used for the Monte Carlo simulation:

- $L$  – uniform distribution: Fig. 1a;
- $r$  – normal distribution: Fig. 2b;
- $k$  – uniform distribution: Fig. 2a;
- $\alpha$  – triangular distribution: Fig. 2b

---

\* Corresponding author. Tel.: +40 744 60 77 38  
E-mail address: camelia.madear@eco-rocca.ro

For the consistency of the units, we have used mm, sec, and mm/ sec.

To run Monte Carlo simulations, we have used @RISK software from Palisade – an add-in to Excel.

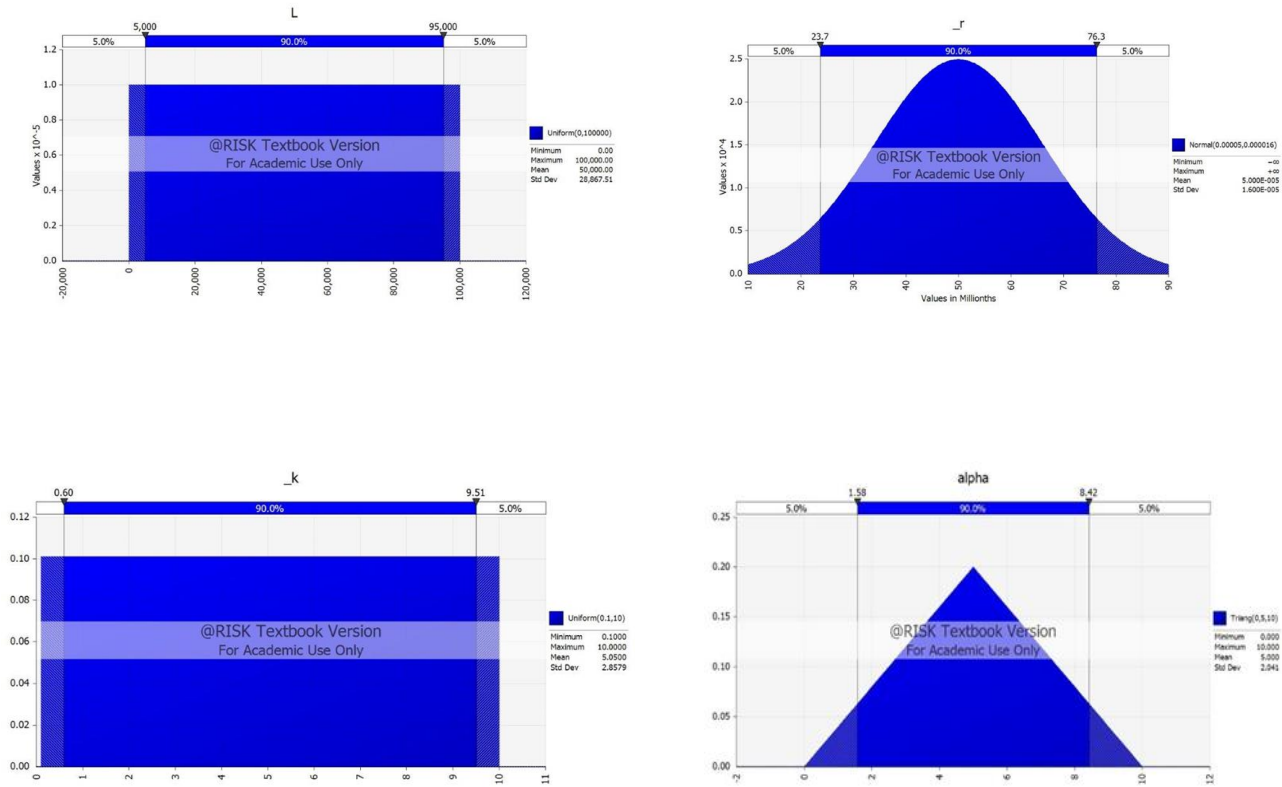


Fig. 1. (a) Uniform distribution for horizontal drainage system; (b) Normal distribution for inflow rate

Fig. 2. (a) Uniform distribution of hydraulic conductivity; (b) Triangular distribution for slope angle

### 3. Maximum Leachate Head by Monte Carlo Simulations

During the landfill design, there are specific requirements regarding the estimation of the maximum liquid head over a barrier, which must always be assessed in two different locations. One of the requirements is to calculate the maximum leachate head over the base of the landfill, and this should not exceed 500 mm. Another requirement refers to the calculation of the maximum saturated depth in the cover system above the barrier and is essential to mention that this is one of the most important parameters which affects the stability of the final cover directly.

The following factors are known that affect the maximum saturated leachate drainage layer: the inflow rate into the drainage layer, the leachate flow distance from the upstream boundary to the leachate collection pipe, the slope of the landfill bottom liner and the hydraulic condition at the downstream and of the drainage layer.

In this paper, we will determine the maximum leachate head over the base of a landfill which is located in Jiu Valley and in order to simplify the calculation and still have relevant results, we will assume that the flow in the drainage layers of the leachate collection system is in a steady flow rate. In this case, the inflow rate will be constant and is assumed to be equal to the maximum inflow rate.

There are several methods to determine the maximum leachate head over a landfill liner; however, we will use for our particular case Moore's 1980 Method, Moore's 1983 Method and Giroud's 1992 Method.

#### 3.1. Moore's 1980 Method

The maximum leachate head can be determined by the formula (1):

$$y_{max} = L \cdot \left(\frac{r}{k}\right)^{\frac{1}{2}} \left[ \left(k \cdot \frac{S^2}{r}\right) + 1 - \left(k \cdot \frac{S}{r}\right) \left(S^2 + \frac{r}{k}\right)^{\frac{1}{2}} \right] \quad (1)$$

where:

$y_{max}$  – maximum liquid head on the landfill barrier;

$L$  – horizontal drainage distance, mm;

$r$  – inflow rate (i.e. rate of vertical inflow to the drainage layer per unit horizontal area), mm/ sec

$k$  – hydraulic conductivity of the drainage layer, mm/ sec;  
 $S$  – slope of the drainage layer,  $S = \tan\alpha$ ;  
 $\alpha$  – slope angle of drainage layer, measured from horizontal, degrees.

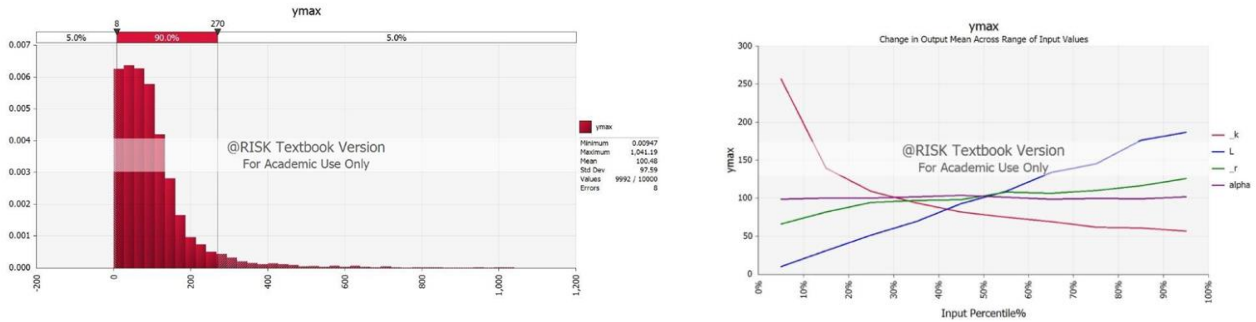


Fig. 3. (a) PDF Model Moore 80; (b) Spider graph Model Moore 80

For Model Moore 80 we ran a Monte Carlo simulation with 10000 realisations.

The resulting Probability Distribution Function is represented in Fig. 5, whereas Fig. 6 shows the influence of each input parameter to the final PDF.

### 3.2. Moore's 1983 Method

Moore presented formula (2) for estimating the maximum leachate head over a sloping barrier in 1983 and is a simpler version of the formula (1) presented in 1980.

$$y_{max} = L \cdot \left[ \left( \frac{r}{k} + S^2 \right)^{1/2} - S \right] \quad (2)$$

where:

$y_{max}$  – maximum liquid head on the landfill liner, mm;  
 $L$  – horizontal drainage distance, mm;  
 $r$  – inflow rate, mm/ sec;  
 $k$  – hydraulic conductivity of the drainage layer, mm/ sec;  
 $S$  – slope of the drainage layer,  $S = \tan\alpha$ ;  
 $\alpha$  – slope angle of drainage layer, measured from horizontal, degrees.

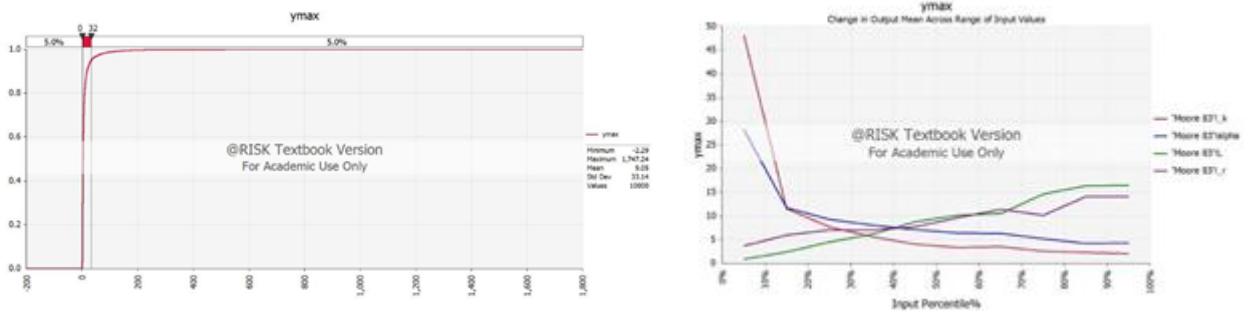


Fig. 4. (a) CDF Model Moore 83; (b) Spider graph Model Moore 83

The same number of realisations has been run for the Model Moore 83, and the Cumulative Distribution Function is shown in Fig. 4a.

The same spider graph – but for Model Moore 83 is presented in Fig. 4b.

This method is less conservative than its previous model.

### 3.3. Giroud's 1992 Method

A different formula (3) was presented by Giroud et al. for estimating the maximum leachate head over a sloping liner.

$$y_{max} = j \cdot L \cdot \frac{\left[ \left( 4 \cdot \frac{r}{k} + S^2 \right)^{\frac{1}{2}} - S \right]}{(2 \cdot \cos \alpha)} \quad (3)$$

The parameter  $j$  in the (3) can be calculated as:

$$j = 1 - 0.12 \cdot \exp\left\{-\left[\log\left(1.6 \cdot \frac{r}{S^2} \cdot \frac{y_{\max}}{L}\right)\right]^2\right\} \quad (4)$$

where:

$y_{\max}$  – maximum liquid head on the landfill liner, mm;

$L$  – horizontal drainage distance, mm;

$r$  – inflow rate, mm/ sec;

$k$  – hydraulic conductivity of the drainage layer, mm/ sec;

$S$  – slope of the drainage layer,  $S = \tan\alpha$ ;

$\alpha$  – slope angle of drainage layer, measured from horizontal, degrees.

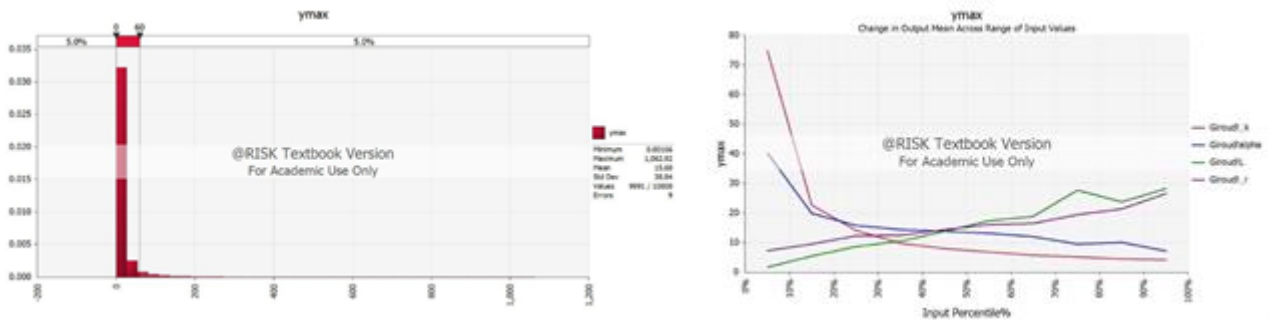


Fig. 5. (a) PDF Model Giroud; (b) Spider graph Model Giroud

Again, we ran a Monte Carlo simulation with 10000 realisations and results are similar to Model Moore 83.

Fig. 5a represents the resulting Probability Distribution Function, whereas Fig. 5b shows the change in output mean across a range of input values.

#### 4. Conclusions

Simple Monte Carlo simulation – each of 10000 realisations, has been run for Moore 80, Moore 83 and Giroud models. The purpose for running a probabilistic analysis was to combine the input parameters – given as ranges and not as deterministic, unique values, and to see how each input parameter influences the final result, maximum leachate head within the drainage layer.

Input parameters are characterised by distribution functions which were derived based on international practice and their influence on the maximum leachate head is shown in spider graphs.

Simulation results are presented either as a Probability Distribution Function (PDF) or Cumulative Distribution Function (CDF), which can be used in the decision making process of the design of the leachate drainage system.

#### References

- Brandusan, C., Cercetari privind reutilizarea terenurilor afectate de activitatile miniere din Valea Jiului pentru depozitarea controlata a deseurilor solide menajere, *Teza de Doctorat*, Universitatea din Petrosani, (2005).  
 Qian, X., Koerner, R.M., Gray, D.H., *Geotechnical aspects of landfill design and construction*, Prentice Hall, (2002).

## A proposed inventory of sustainable development indicators for the manufacturing process assessment

Corina Dufour<sup>a\*</sup>, Larisa Ivascu<sup>a</sup>, Adrian Mateescu<sup>a</sup>, Anca Draghici<sup>a</sup>

<sup>a</sup> Politehnica University of Timisoara, Pta Victorie 2, 300222 Timisoara, Romania

---

### Abstract

Today, new challenges in developing sustainable management models, particularly for manufacturing processes, have emerged because of the new demands imposed internationally for various industrial processes as: resource management (reduce waste and resource efficiency), cleaner production and technologies, recycling and reuse, improving social conditions, better working conditions etc. Operation management models such as Lean Manufacturing and Value Stream Mapping (VSM) have contributed to the development of manufacturing processes by reducing waste in the production flow. This paper aims to propose a conceptual method to integrate a new group of sustainable development indicators into the VSM model to better support the sustainability perspective to the manufacturing process assessment process. Furthermore, the paper discusses how the inventory of the sustainable development indicators was designed (has been considered and selected) based on the literature review in this field. The proposed method will be described together with some considerations for its practical exploitation in different manufacturing processes. The research results have an important contribution to the literature in the field, because of the proposition of new sustainability indicators related to the manufacturing process.

*Key words:* Sustainability indicators; Lean Manufacturing; Value Stream Mapping; Manufacturing process

---

### 1. Introduction

Operation management approaches have evolved over a period to adapt to the new challenges of sustainable development and competitiveness. In this context, Value Stream Mapping (VSM) has been recognized as an excellent tool for process mapping (Braglia et al, 2011) and is used for the of “leaning” industries to make them both more responsive and more competitive (Dinesh and Vaibhav, 2007). Historically, in manufacturing process, responsiveness and competitiveness were measured through indicators such as production costs, time to market or stock costs. Increasing customer interest and awareness of environmental and social impact have steered manufacturing companies to follow-up new indicators related not only to the traditional economic dimension, but also to environmental and social dimensions, giving birth to sustainable manufacturing.

In the context of the present article, there will be considered the integration of VSM approach (and model), sustainable development (with respect to the dimensions given by the Triple Bottom Line model) in the case of manufacturing systems with the purpose of proposing a new method for the integration of environmental, social and economic indicators in the VSM model. Thus, the sustainable development assessment process in the case of manufacturing will be more accurate.

The article starts with a first section presenting a two-parts literature review on sustainable development and the VSM approach, followed by a debate on sustainable development in the manufacturing context. Follows a proposed conceptual method for including (integrating) in the VSM approach, an aggregated indicator that mirrors the influence of environmental and social indicators on the value added (as per calculated in the VSM). In the end, some final conclusions and future research fields are presented.

---

\* Corresponding author. Tel.: +40-256-403610; fax: +40-256-403610.  
E-mail address: corina.dufour@student.upt.ro

## 2. Literature review

### 2.1. Sustainable development and manufacturing

Manufacturing is critical from the standpoint of sustainable development as it has important environmental and social impacts and is, in the meantime, crucial to economy (Lucato and al, 2017). This has been strained even more as the United States Department of Commerce embedded sustainable development into manufacturing by defining sustainable manufacturing: “the creation of a manufactured product with processes that have minimal negative impact on the environment, conserve energy and natural resources, are safe for employees and communities, and are economically sound” (Faulkner and Badurdeen, 2014; Joung et al, 2013; Feng and Joung, 2009, OECD, 2011). It is inferred from this definition that both the final product and the manufacturing process must be sustainable (Faulkner and Badurdeen, 2014).

Enhancement of manufacturing processes is a challenging field as the manufacturing process is characterized by the existence of several sub-processes, the assessment of which can be complex or incomplete (Kluckek, 2017). Although considerable work has been undertaken in advancing the understanding of sustainable development indicators, literature stresses the need for a clear measurement system, as well as implementation methods (Mani et al, 2014; Veleva & Ellenbecker 2001; Brown and al, 2014; Azapagic and Perdan, 2000). More so, many initiatives are intended for external communication rather than adapted for internal steering (Feng and Joung, 2009).

The bulk of literature was selected by including works that address at least three sustainable development dimensions with the purpose of categorizing the type(s) of metric(s) used: aggregated or non-aggregated. Although, Joung et al (2013, p. 150) distinguish indexes and indicators (“aggregating several indicators through weight-based mathematical methods” vs “a measure or an aggregation of measures from which conclusions on the phenomenon of interest can be inferred”), the authors shall use the term “aggregated indicator” for all measures obtained by a mathematical method and the term “non-aggregated indicator” for all measures obtained through observation, measurement or appreciation.

After reviewing public frameworks, repositories, methodologies and/or indicator sets, many authors point to the need of more clarity regarding the harmonization of indicators (Joung et al, 2013; Veleva & Ellenbecker, 2001; Azapagic and Perdan, 2000; Feng and Joung, 2009). They emphasize the absence of one or several dimensions (Joung et al, 2013; Veleva & Ellenbecker, 2001; Kluckek, 2017; Eseoglu and al, 2014), the number of indicators to be assessed (Veleva & Ellenbecker, 2001) or the limited instructions for implementation (Veleva & Ellenbecker, 2001). As most publicly available indicator sets have already been reviewed extensively in research literature, the selected articles refer to manufacturing industry as a whole, a specific sector of the manufacturing industry or across industries.

It was concluded that on a general basis, and regardless of the type of indicator (aggregated or non-aggregated) ultimately assessed, the implementation of sustainability in the manufacturing industry requires choice of appropriate indicators and measurement procedure (measurement method and acquiring of data) and finally data analysis, decision-making and impact evaluation (Joung et al, 2013, Azapagic and Perdan, 2000). If Azapagic and Perdan (2000) favor a given-basis assessment for defining progress, Joung et al (2013) point to the necessity of setting goals next to which progress can be compared. The poor applicability of the indicators sets at the operational levels is also pointed often (Veleva & Ellenbecker, 2001; Zackrisson et al, 2017; Lucato and al, 2017), as the necessity for less time-consuming approaches is stressed. A noteworthy approach is suggested by Azapagic and Perdan (2000) through their indicator categorization approach which proposes that training and health and safety belong to the economic sphere rather than the more traditional social sphere and should be interpreted in correlation with the indicators of the environmental dimension of sustainability on which they have a direct impact. This goes in the direction of the finding of Zackrisson et al (2017) regarding sustainability indicator interconnection.

In the case of aggregated measurements, supplementary safeguards must be implemented. Lucato et al. (2017) define the sustainability level as the area of the triangle obtained in an orthogonal system, where the axes are defined by the three sustainability dimensions and thus special considerations need to be given to the measurement unit and to the same direction influence of indicators on performance.

Table 1 summarizes the literature review according to the type of sustainability measurement, main sources for indicator selection, the specificity to an industry and, in the case of aggregated indicators, the aggregation method.

Following the literature review, we have concluded that the assessment of sustainable development for manufacturing processes is characterized by the absence of a plebiscite framework, assessment method or indicator set; this derives from the numerous initiatives and wide definition of sustainable development.

Table 1. Categories of sustainability measurement in manufacturing literature

Reference	Type of Sustainability Measurement	Industry Specific	Main Source	Aggregation Method
Azapagic and Perdan (2000)	Non-Aggregated (35 indicators)	Cross-industry	Life Cycle Approach	NA
Delai and Takahashi (2011)	Non-Aggregated	Manufacturing	Global Report Initiative (GRI) Institution of Chemical Engineering (ICHEME)	NA
Eseoglu and al (2014)	Non-Aggregated	Manufacturing	Literature review Regulations Trends	NA
Feng and Joung (2009)	Aggregated	Manufacturing	Literature review	Metric aggregation and Life Cycle Approach
Joung et al (2013)	Non-Aggregated (200 indicators)	Manufacturing	Global Report Initiative Dow Jones Sustainability Index, 2005 Environmental Sustainability Indicators, Environment Performance Index, United Nations-Indicators of Sustainable Development, Organization for Economic Cooperation and Development Core Environmental Indicators, Ford Product Sustainability Index, ISO Environment Performance Evaluation -14031, Environmental Pressure Indicators for European Union	NA
Kluzeck (2017)	Aggregated (8 activity areas)	Manufacturing	Research literature review	Analytical hierarchy process
Lucato and al (2017)	Aggregated (as defined by the user)	Manufacturing	As defined by the user	Representation with vectors in cartesian orthogonal reference system
Veleva & Ellenbecker (2001)	Non-Aggregated (22 indicators)	Production	Global Report Initiative (GRI) and ISO 14031	NA
Zackrisson et al (2017)	Non-Aggregated (3100 indicators)	Manufacturing, shop floor	United Nation Sustainable Development Goals, ISO 26000 Guidance on Social Responsibility, Global Compact, Global Reporting Initiative (GRI) and objectives Empirical study based on company indicators	NA
Amrina and Yusof (2011)	Non-Aggregated	Automotive industry	Literature review	NA

## 2.2. Sustainable development and Value Stream Mapping

Value Stream Mapping (VSM) can be defined as “the process of mapping the primary raw material and information flows in converting raw material to finished product or creating a service of value that a customer is willing to pay for.” (Martin, 2013). VSM is intensely used in lean approaches as the easy-to-understand mapping (Faulkner and Badurdeen, 2014) allows rapid identification of waste. VSM is also an important tool for decision makers as it gives a holistic perspective with a clear representation of the flow of information (Martin, 2013) and thus can fill the void of a more hands-on-deck approach. Its main strength resides in being easily comprehensible and highly visual, and as such literature points out, to the danger of overcrowding the VSM by integrating supplementary social and environmental indicators (Faulkner and Badurdeen, 2014; Brown and al, 2014). On the other hand, such integration can induce important gains in terms of cost, image, quality and lead time (Yusof et al, 2013). The difficulty related to the adding of sustainable development metrics to the VSM resides in the aspects of the metrics themselves, which, despite several initiatives from industry, research and regulatory bodies are neither standardized, nor do they capture accurately the risks to which employees are exposed to (Faulkner and Badurdeen, 2014; Brown and al, 2014). These findings are coherent with those of the previous chapter of the article.

Faulkner and Badurdeen (2014) are among the pioneers proposing an approach for the visualization of the sustainability of manufacturing processes by combining Value Stream Mapping and sustainable development in the approach “Sustainability-VSM” (Sus-VSM). They add supplementary indicators regarding environmental and social



dimensions as well as the necessary graphic representations, to the traditional VSM method and time-based metrics. Their proposal for the selected indicators for the environmental dimension of manufacturing included three metrics (process water consumption, material usage, energy consumption) and the social dimension by two metrics pertinent to the most impacted stakeholder, which are the employees (physical work and the work environment).

Brown and al (2014) have approached Sus-VSM by developing the works of Faulkner and Badurdeen (2014) and applying the Sus-VSM to different configurations of the manufacturing environment (job shop, flow shop, cellular). Thus, the conventional VSM approach was implemented by adding economic indicators; questionnaires were added for the assessment of the two social indicators (job hazard and ergonomics) and technical data for the environmental indicators (energy and water consumption). The difficulties in implementing the Sus-VSM model are similar to those for the traditional VSM with regards to the configuration of the manufacturing process, but the collection of data related to the environmental and social dimensions is far more an endeavor as opposed to the economic dimension.

Yusof et al (2013) has later modified the conventional VSM by calculating, for each dimension of sustainability, the sustainable score (ratio of the value adding metric over the non-value adding metric) and by aggregating it into a general sustainability score for the entire process. The non-value-added activities will then be improved through the implementation of the 6R method (reduce, reuse, recycle, recover, redesign and remanufacture).

Finally, it was concluded that the difficulties regarding the implementation of sustainable VSM are less related to the structure or methodology of the VSM for which Faulkner and Badurdeen (2014) proposed an extension, but to the definition and measurement of the sustainability indicators themselves and by defining the methodology for their joint assessment rather than individual. Table 2 presents a categorization of the literature review on sustainable VSM of manufacturing processes by the type of sustainability measure. Furthermore, based on the literature review it was concluded that issues related to the selection of indicators and application of a designed framework are common limitations of assessing sustainable manufacturing in general, and through VSM particularly. The few approaches that include an aggregated indicator for the influence of economic, social and environmental dimensions, are time-consuming and difficult in floor-shop implementation. As such, in the context of the present research there will be proposed, in the next section, an approach for the assessment of sustainability performance in association with the VSM model, independently of the selection and choice of indicators and inducing a diminishment of the value added for social and environmental draw-backs.

Table 2. Categorization of sustainability measure regarding the Sus-VSM approach in the literature (alphabetical order)

Reference	Type of Sustainability Measure
Brown et al. (2014)	Non-Aggregated
Faulkner and Badurdeen (2014)	Non-Aggregated
Yusof et al. (2013)	Aggregated

### 3. The Proposed Conceptual Model

The literature review pointed out that only intertwining social, economic and environmental indicators can lead to a real measure of sustainability (Joung et al, 2013). In the present research it has been considered that an aggregated approach for the measure of sustainability is more appropriate than a non-aggregated approach as it can give a global, holistic vision and can allow much easier steering and benchmarking. As a pillar economic indicator in value stream mapping, value added, is the object of considerable Lean effort. What is more, value added is also an aspect of manufacturing that appeals to the end customer, as it is a concept within his grasp. In accordance with Azapagic and Perdan (2000) research, in the present approach it has been considered that regardless of the methodology of calculation of value added, in collaboration with other indicators it can give a pertinent measure of sustainable development.

The proposed model enriches the field of aggregated measures for sustainability within manufacturing. The novelty of this model resides in the fact that it can be used for any social and environmental indicators of the manufacturing process through the introduction of a new concept Sustainable Value Added (Sus-VA). Thus, this conceptual framework is compatible with the indicators for which data is available through stable and repeatable measurements, and for which analysis is possible. According to our preliminary development, it was considered that any environmental and social indicator has an influence on the value added of the final product and that by computing the influence of social and environmental indicators on the value added, a new measure of sustainability can be obtained: Sustainable Value Added (Sus-VA). It is defined as the value added of the final product which is the result of a manufacturing process and which considers the environmental, social and economic impacts of the manufacturing process. Sus-VA can be calculated according to equation (1), where VA is the value added according to the calculation in the traditional VSM approach and *EnSolx* is the Environmental and Social Index.

$$SusVA = VA \times EnSolx \quad (1)$$

In the context of the proposed approach, the Environmental and Social Index (EnSoIx) is defined as the aggregated index of environmental and social indicators evaluated for every process (as per manufacturing unit VSM) on a scale between 0, as the lowest graduation and the target of the organization (as per company strategy). For each manufacturing process, there will be considered the social indicators defined by equation (2) and the environmental indicators defined by equation (3):

$$s_i^j, i \in (1, m) \quad \text{and} \quad j \in (1, n), \quad (2)$$

$$e_i^j, i \in (1, p) \quad \text{and} \quad j \in (1, n), \quad (3)$$

In equation (2) and (3), “m” is the number of social indicators for the manufacturing process “j” and “p” is the number of environmental indicators for the manufacturing process “j”. In this conceptual framework, each indicator is determined within the minimum and the target goal and is then transformed into a percentage of achievement for being included in the model final report. The percentage of achievement in the case of social indicators ( $\%s_i^j$ ) and of environmental indicators ( $\%e_i^j$ ) are calculated using equations (4) and (5):

$$\%s_i^j = \frac{s_i^j}{\text{target}(s_i^j)}, \quad \text{with } \%s_i^j \in [0, 1] \quad (4)$$

$$\%e_i^j = \frac{e_i^j}{\text{target}(e_i^j)}, \quad \text{with } \%e_i^j \in [0, 1] \quad (5)$$

As through its fundamental definition sustainability is achieved through the balance of its three dimensions: economic, social and environment. Thus, there have been considered that there is no need to propose a hierarchy of indicators. This would also avoid introducing subjective bias in the evaluation. With these assumptions, the average social and environment indicators for a given process are then computed based on the mean of the indicators, as shown by the equations (6) and (7) respectively.

$$\overline{s}^j = \frac{\sum_{i=1}^m s_i^j}{m} \quad (6)$$

$$\overline{e}^j = \frac{\sum_{i=1}^p e_i^j}{p} \quad (7)$$

Finally, the EnIx is the environmental index for the manufacturing unit and is computed as the average of the mean environmental indicator for each process, according to equation (8). Similarly, the SoIx is computed as the average of the mean social indicator for each process, according to equation (9).

$$EnIx = \frac{\sum_{j=1}^n \overline{e}^j}{n} \quad (8)$$

$$SoIx = \frac{\sum_{j=1}^n \overline{s}^j}{n} \quad (9)$$

The EnSoIx of the manufacturing unit, will be the average of the EnIx and the SoIx of the unit, as shown by the equation (10).

$$EnSolx = \frac{EnIx + SoIx}{2} \quad (10)$$

#### 4. Conclusions

The literature review has pointed out that the measurement for sustainability needs a more integrated approach of the environmental, social and economic dimensions. Such approaches remain scarce in the field of sustainable manufacturing and even more so for a compound usage with other Lean techniques such as Value Stream Mapping. One of the most commonly assessed indicators through VSM is value added, which is limited to the economic sphere, but could be used, in conjunction with social and environmental indicators, as a measure of sustainability in manufacturing.

The proposed conceptual framework introduces a novel concept: Sustainable Value Added. Sus-VA is calculated as an aggregated indicator for sustainable manufacturing, based on the value added as computed through the conventional VSM weighted by the Environmental and Social Index (EnIx and SoIx). Sus-VA delivers a unique measurement of sustainability for manufacturing processes regardless of the advancement of a company on the sustainability path (it could monitor the level of development). In addition, this approach includes social and environmental indicators that the company chooses to consider in the value stream, with the limitation that the value stream is impacted by the subjective choice of indicators (according to company strategy). In order to avoid this aspect, stakeholders and shareholders should be involved in the final analysis and decision.

The main advantage of the proposed conceptual framework is that it induces a social and environmental weighing of the conventional value added; it can be used as a tool for internal steering, benchmarking and external communication. Another advantage is that the framework can include upstream and downstream impacts on the final product if the VSM was drawn up to include these elements and if the traditional value added was computed for the entire chain.

Further research should include an application of the conceptual model for empiric validation (establish the set of indicators for a specific industrial field and/or a particular manufacturing unit), consideration of inclusion of the life cycle approach within the model and understanding of how the Sus-VA can be improved through Lean techniques.

## References

- Amrina E., Yusof, S.M., Key performance indicators for sustainable manufacturing evaluation in automotive companies, *2011 IEEE International Conference on Industrial Engineering and Engineering Management*, Singapore, pp. 1093-1097, (2011).
- Azapagic, A., Perdan, S., Indicators of Sustainable Development for Industry: A General Framework, *Process Safety and Environmental Protection*, Vol.78, pp. 234-261, (2000).
- Braglia, M., Carmignani, G., & Zammori, F., A new value stream mapping approach for complex production systems. *International journal of production research*, Vol. 44, No. 18-19, pp. 3929-3952, (2006).
- Brown, A., Amundson, J., Badurdeen, F., Sustainable value stream mapping (Sus-VSM) in different manufacturing configurations: application case studies, *Journal of Cleaner Production*, Vol.85, pp.164-179, (2014).
- Dal Forno, A.J., Pereira, F.A., Forcellini, F.A., Kipper, L.M., Value Stream Mapping: a study about the problems and challenges found in the literature from the past 15 years about application of Lean tools, *The International Journal of Advanced Manufacturing Technology*, Vol.72, No. 5-8, pp. 770-790, (2014).
- Delai, I., Takahashi, S., Sustainability measurement system: a reference model proposal, *Social Responsibility Journal*, Vol. 7, No. 3, pp. 438-471, (2011).
- Dinesh, S., Vaibhav, G., Application of value stream mapping for lean operations and cycle time reduction: an Indian case study, *Production Planning and Control*, Vol.16, No.1, pp. 44-59, (2007).
- Eseoglu, G., Vayvay, O., Zeynep, T. S., Assessment of Sustainability Performance Indicators in Manufacturing, *Proceedings of Global Conference on Engineering and Technology Management* (2014).
- Faulkner, W., Badurdeen, F., Sustainable Values Stream Mapping (Sus-VSM): methodology to visualize and assess manufacturing sustainability performance, *Journal of Cleaner Production*, Vol.85, pp.8-18, (2014).
- Feng, S. and Joung, C., An Overview of Proposed Measurement Infrastructure for Sustainable Manufacturing, *Proceedings of the 7<sup>th</sup> Global Conference on Sustainable Engineering*, December 2 - 4, Chennai, India (2009), Retrived from: [https://ws680.nist.gov/publication/get\\_pdf.cfm?pub\\_id=904166](https://ws680.nist.gov/publication/get_pdf.cfm?pub_id=904166) (Access on 28 August, 2018).
- Joung, C.B., Carrell, J., Sarkar, P., Feng, S.C., Categorization of indicators for sustainable manufacturing, *Ecological Indicators*, Vol.24, pp. 148-157, (2013).
- Kluckzek, A., An overall multi-criteria approach to sustainability assessment of manufacturing processes, *Procedia Manufacturing*, Vol. 8, pp. 136-143 (2017).
- Lucato, W.C., Santos, J.C., Pacchini, A. P. T., Measuring the Sustainability of a Manufacturing Process: A Conceptual Framework, *Sustainability*, 10 (1), p. 81, (2017).
- Mani, M., Madan, J., Lee, J.H., Lyons, K.W., Gupta, S.K., Sustainability characterization of manufacturing processes, *International Journal of Production Research*, Vol. 52, No. 20, pp. (2014).
- Martin, C., *Maximized Value Stream Mapping – Theory and practical application case study*, APICS, (2013).
- OEDC, *Sustainable Manufacturing Toolkit*, (2011). Retrived from: <https://www.oecd.org/innovation/green/toolkit/> (Access on 28 August, 2018).
- Veleva, V., Ellenbecker, M., Indicators of sustainable production: framework and methodology, *Journal of Cleaner Production*, Vol. 9, pp. 519-549, (2001).
- Yusof, N.M., Saman, M.Z.M., Kasava, N.K., A conceptual sustainable domain value stream mapping framework for manufacturing, *11<sup>th</sup> Global Conference on Sustainable Manufacturing*, 23-25 September, Berlin, Germany (2013).
- Zackrisson, M., Kurdve, M., Shabazi, S., Wiktorsson, M., Winroth, M., Landström, A., ... and Myrelid, A., Sustainability performance indicators at shop floor level in large manufacturing companies, *Procedia CIRP*, 61, pp. 457-462, (2017).

## Quality assessment of Petroșani urban landscape

Grigore Buia<sup>a</sup>, Ciprian Nimară<sup>a\*</sup>

<sup>a</sup>University of Petroșani, University Street, no.20, Petroșani, 332006, Romania

---

### Abstract

The landscape is the world around us, including everything we see or feel wherever we are. It is continuously in space and time: in space as a series of physical and social events, and over time as a continuity of these events that constantly change the space. Through this paper we wanted to make a quality assessment of the urban landscape of Petroșani town to highlight certain characteristics specific to the mono-industrial towns, which identity was lost along with the territorial, urban and socio-economic evolution

*Keywords:* landscape, quality assessment, urbanism, visual impact, Petroșani;

---

### 1. Introduction

The landscape is an important resource, being a remarkable natural and cultural heritage that is appreciated for its beauty and aesthetics, but also its contribution to the identity of a region. Beyond the way the landscape highlights some ways to look at the world, it also puts us face to face with the issues of nature and the way we relate to it. On the other hand, urban and industrial development requires us to talk about urban landscape, industrial landscape, or technological landscape (Bold O., Nimară C., 2016).

Numerous definitions of "landscape" and "geographic landscape" have been imposed over time. Most of them refer to the "landscape view", to the concrete elements of the landscape and the relationships between them, avoiding its subjective reality. Even if the emphasis is on the objective reality of the landscape, that is what is measurable, palpable, concrete, it becomes at one point a subjective reality (consequence of the human perception process). Hence, the landscape is a dual, objective and subjective reality to the same extent (Baciu N., 2014).

The landscape designates a part of a territory perceived as such by the population, the character of which is the result of the action and interaction of natural and/or human factors. The perception of the landscape by the community is a process of cognitive nature that implies the recognition by community members of common values of patrimony with great significance to the community. The principle of community participation aims to provide the public with the opportunity to express their views on the identified landscapes and to participate in landscape identification (Armaș I., 2006). Petroșani town, which corresponds to the geographical coordinates 45°24'44 " latitude N and 23°22'24" longitude E, with an area of over 20,000 ha and a population of 37,160 inhabitants is the largest locality in the Jiu Valley (Petroșani Depression).

By the number of inhabitants, it occupies the third position in the area and at the same time is the most important center of the mining industry in the country. It is located in the southern Carpathians, at a height of 500 m, well connected with the peaks of the Parâng Mountains in the East, Șureanu Mountains in the North-East, the Vâlcan Mountains in the South and the Retezat Mountains in the North and North-West.

### 2. Urban landscape of Petroșani town

The urban landscape of Petroșani town is part of the category of landscapes belonging to mono-industrial towns which territorial development has led, especially during the industrialization, to the loss of some patrimony buildings or, if they have escaped being demolished, in the post-communist period, with the restitution of former owners or their heirs to staying in various stages of degradation (For example Ianza Castle and colony).

---

\* Corresponding author. Tel.: +0040 762 115 633  
E-mail address: ciprian.nimara@yahoo.com

The architectural style of the buildings differs, depending on the period in which they were built, being present in the landscape buildings that were built at the end of the 19<sup>th</sup> century (the Evangelical Church, the Roman Catholic Church), the beginning of the twentieth century (Ianza Castle, the Worker's Casino, the No. 1 Comprehensive School, Orthodox Church, Unitarian Church etc.) as well as buildings built after 1980, these being mostly blocks of flats and various cultural or administrative buildings (Figure 1).



Fig. 1. Landscape view of Petrosani town

Soil degradation due to underground exploitation may occur within the mining area located on the territory of Petrosani. Industrial waste resulting from technological processes and industrial activities carried out by economic agents consists of: sterile dumps, metal waste, sludge, wood wastes and other types of waste.

The sterile dumps located on the territory of Petroșani town come from E.M. Dâlja, E.M. Livezeni, U.P. Livezeni and E.M. Petrila South. The sterile dumps, as well as the access roads to them are arranged on expropriated land. The sterile dump is the result of investment works following the sorting of coal.

### 3. Visual impact analysis

The landscape is an instrument of territorial design and development, with changes in the national economy accelerating the transformation of the landscape. Defining elements that condition the landscape are *form* and *history*, and landscape analysis and reading requires knowledge of the structure and materials that make up the landscape.

In the definition and perception of the landscape, different approaches were taken, the best known being:

- approaching the *objective landscape* characteristic of the Soviet school. This approach focuses on the correlations between physico-chemical factors, soil and biotic support. Objective landscape analyzes cast out man and anthropic construction and refer to pure natural terrain, difficult to trace in reality.
- approaching the *subjective landscape* characteristic of the French school, which falls in the extreme of the subjectivism of perception, of the links with art, philosophy and the history of the landscape. However, it is worth noting that the French school has made significant contributions to the holistic landscape and has accentuated the areas of perceived landscape, lived landscape, landscapes created (parks and gardens).

Basically, the landscape can not exist without a man, the latter interfering with the landscape and modifying it according to its needs (Eg. changing the landscape to increase the tourist value of some sites).

The objective bases of analysis (Table 1 and Table 2) of the urban landscape of Petroșani town are:

- the relief, represented by the slightly elongated intra-mountain depression, with the hilly foundation, the neighboring scenery being visible the piedmonts (Dâlja Piedmont and Maleia Piedmont) as well as the Parâng and Vâlcan mountains;
- natural elements more or less compete with visual harmony through diversity;
- the built elements are testimonies of the presence of man and reveal an obscure value, not negligible to an observer and constitute an important element of the landscape.

Table 1. Analyze point of urban landscape by major structures

Territorial system framing	Mountain framing	Structural framing	Administrative framing	Geomorphological framing
Large area (1-10 km <sup>2</sup> )	Mountain landscape	Terrestrial landscape	Urban area	Depression landscape

Table 2. Analyze point of urban landscape by natural and anthropic indicators

Biology and soil	Climate	Culture and history	Social-economic framing	Dynamic state of operation
Coniferous and mixed forest, brown soils, grey woods soil and clay soils	Mountain climate with temperature inversions	Modern and contemporary architectural values	Mining activities, commercial activities, residential areas, tourist or recreation areas	Modified structures, degraded structures, irreparable structures

The cultural landscape of the urban peripheries is a distinct type of urban landscape, as a result of an environment in the same destiny with the city, in the prolongation of which it is established, undermining its existence on the one hand, on the one hand, and on the other hand, an alternative.

The cultural landscape of the urban outskirts is a landscape in transition, a contradictory resource, corresponding to a process of changing the reference systems across the entire urban system, including indeterminacy, disorder, vague, incoherence, absence. Despite its often desirable, aesthetically pleasing appearance, the landscape's cultural landscape is one of authenticity and potential, giving urban culture a consistent regeneration field.

The criteria for identifying the landscape are part of the methodology elaborated on the basis of 451/2002 Law for the ratification of the European Landscape Convention. The Convention takes into account international legal sources in the field of protection and management of natural and cultural heritage, land-use planning, local autonomy and cross-border cooperation.

#### 4. Quality assessment of Petroșani urban landscape

From a qualitative point of view, an evaluation was made taking into account 13 indicators, as can be seen in the following table (Table 3):

Table 3. Quality assessment of urban landscape

Name of indicator		Value		
		Low	Medium	High
Buildings and historical monuments	19 <sup>th</sup> century	X		
	20 <sup>th</sup> century	X		
Buildings and constructions of new architectural value after 1989		X		
Buildings built between 1950 and 1989				X
Green areas, parks and recreation areas			X	
Pedestrian assemblies, public squares		X		
Homogeneity of architectural style		X		
Visible homogeneity in height		X		
Visual homogeneity as shape and structure			X	
Aesthetic contrast between buildings (shape, structure, color)			X	
Detached, demolished or demolished buildings		X		
Contrast on residential areas			X	
Accessibility between functional areas				X
Industrial zones in operation		X		
Decommissioned industrial zones		X		
The visual and qualitative aspect of the transport infrastructure			X	

#### 5. Conclusions

Through this paper we wanted to make a quality assessment of the urban landscape of Petroșani town to highlight certain characteristics specific to the mono-industrial cities, which identity was lost along with the territorial, urban and socio-economic evolution.

Most of the time, the focus is on the objective reality of the landscape, which is measurable, palpable, concrete, but it becomes at one point a subjective reality, being a consequence of the process of human perception. Hence, the landscape is a dual, objective and subjective reality to the same extent.

The quality assessment of landscape is a process that is aesthetically related to a subjective value scale that is often the cultural, educational, understanding, and style of each subject or respondent. It refers to the natural, cultural or urban landscapes that it has been seen or analyzed previously. Most of the time, the quality assessments of the landscape or the environment have been countered by the assessment scale used in the form of qualitative values: high, medium or low.

## **Refernces**

Armaş I., *Teorie şi metodologie geografică*, Editura Fundaţiei România de Măine, Bucureşti, (2006).

Baciu, N., *Dinamica şi tipologia peisajului*, Editura Bioflux, Cluj Napoca, (2014).

Bold O., Nimară C., *Peisagistică naturală şi antropică*, Editura Universitas, (2016).

\*\*\* Landscape Institute, Institute of Environmental Management and Assessment (I.E.M.A), Guidance for Landscape and Visual Impact Assessment Second Edition, (2002).

\*\*\* Planul de amenajare a teritoriului zonal Valea Jiului;



## The underground space, a solution for the protection of the environment

Daniela Ionela Ciolea<sup>a\*</sup>, Emilia Cornelia Dunca<sup>a</sup>

<sup>a</sup> University of Petrosani, Universitatii Street, no. 20, 332006 Petrosani, Romania

---

### Abstract

The research, concerning the development of underground facilities worldwide, it indicates that both a favourable environment for the use of the underground space (or space location understood as great) and a boost to the adoption of the method are required to achieve the underground construction of major underground facilities. A major incentive for the use of underground space is growing international concern on the environment, which led to rethinking future urban construction and industrial. It is clear that increased pressure on the use of terrestrial lead to two trends already present in many countries, or the construction of high-rise buildings or use scale growing facilities of underground space, variant seems however, it is the most advantageous. In this context it is important to plan new type of underground facilities wisely. Planning must be effectively controlled and used to maintain the natural surface and side effects involved in the development of underground projects are anticipated.

*Keywords:* underground space, the environment, the use of underground space, construction

---

### 1. Introduction

The increasing world population and rapid development of modern society will have a significant impact on the livelihoods of people in the future, leading to higher living standards, increasing consumption of food, energy and minerals. Due to population growth, urbanization and economic growth this earth must now support transport systems extensive industrial development and trade and growing demand for housing, so that the area under agriculture decreases gradually since the seats flat and generally fertile they initial development was places historically.

A major incentive for the use of underground space is growing international concern on the environment, which led to rethinking future urban construction and industrial.

The largest underground city in Cappadocia, Derinkuyu was discovered only in 1965, when one of the region's residents cleans up in a room of his house.

Finally, archaeologists and speleologists have discovered that behind the wall hiding a real underground city, which stretched at least 18 stories underground to a depth of about 85 meters, and can accommodate about 30 000 people.

In fact, experts have not fully explored even today underground city of Derinkuyu.

### 2. The current state of the underground space

Environmental damage caused in the last century has significantly reduced quality. In this respect good knowledge of damage caused to the environment in developed countries use obsolete technologies affecting the environment in poor countries with environmental pressure due to overpopulation and increasing needs, promotes better understanding of the phenomenon of environmental pollution and enables us to take appropriate action to protect it.

But environmental damage is done not only because of human error or technical accidents but also due to cultural approaches inadequate or blind economic policies.

Accumulation of quantities in recent years increasingly more waste owing to increased human activities, process reported worldwide, raises very important economically and environmentally.

---

\* Ciolea DI. Tel.: 0751081047.

E-mail address: cdipentrucdi@yahoo.com.

Thus, it is estimated that between growth rate and the volume of waste there is a proportional relation, which contributes to the worsening conflict in the modern age of technology, on the one hand and ecology on the other. The massive increase discharges of waste and toxicity of a good part of their content jeopardizing the ability of the environment to assimilate them.

The emission and waste discharge into the environment of the initial stage of the process is pollution, followed by reaching the ambient concentrations in the quality of the biological environment.

Therefore a fundamental objective of any policy and strategies for environmental protection is to reduce the amount of waste from production and consumption patterns as a result.

Such an objective can be achieved by way of recycling, reconditioning or recovery of waste and deposit them in appropriate conditions to eliminate any possibility of environmental pollution. But desirable as better integration of environmental concerns into consumption and production schemes.

According to statistics and international studies, the quantities of waste generated in each country and the average per capita was related to the degree of development and urbanization, the type of technology applied in the production of specific and consumption patterns, income levels and lifestyle population.

However, the level of development and civilization leaves its mark on the business of environmental protection waste pollution.

Effective waste management in the context of sustainable development refer the following dilemma: waste disposal or recovery of the amount remaining under the restrictions of cost and the environment.

The aim in waste management is to maximize the preservation of non-renewable resources and neutralizing negative effects on the environment.

So the concept of the cultural sector can be characterized by including waste issues within the general actions for environmental protection, given that any waste which is not used or neutralized, pollute the environment.

Currently in developed countries of the total expenditure on environmental protection:

- 20 ÷ 25 % of which are intended to be recovered by recycling useful minerals and the costs incurred are recovered;
- 75 ÷ 80 % are for the collection, neutralization, elimination and / or economically non-recoverable waste disposal.

In Romania, the costs for the collection, transportation, disposal and storage of waste solids is about 27 % of the total expenditure for environment protection, reflecting a relatively small and insufficient concern.

The ratio of investments for the recycling of waste and waste pollution protection is negligible, less than 1 % of the total investment. Meanwhile developed countries spend for this area, between 5 and 15 % of total investments.

Reported per capita total annual waste in Romania is about 12 tons compared to about 10 tons as the media representatives on all countries in Western Europe.

The differences between the two levels can be explained by: character structure of the economy and lack of funds; outdated technology; lack of continuing concerns for the environment.

The highest weights are held in our country waste resulting from underground mining and quarrying - over two fifths. In terms of the amount of waste dumps and tailing ponds is the most important source of environmental pollution. Evaluate all over the country, about 360 million tons, which make up the waste deposits and tailings ponds current production resulting from the activity occupies an area of 11.600 hectares, which is equivalent to about 0.08 % of the total agricultural area of Romania 0.12 % of total arable land.

Of the total area occupied by waste dumps and tailing ponds have been provided up to now, about 9 %. If they are supplemented ash, slag and waste ore metallurgical processing, shows that over 70% of solid waste pollution due to industrial activities freely. In Romania of over 2 million tons of waste annually, representing about 95 % of industrial waste. (Wegner, 1993) Although difficult and costly removal and disposal remains the central issue of environmental strategy.

Methods of waste disposal, the most used is deposition on land or burial ground (especially for municipal waste, in Romania there are currently only two landfills and no ecological waste incinerator). So costs are low, this presents a high risk of pollution by high potential for groundwater contamination, soil and explosion through gas accumulation.

In these circumstances the main objective of sustainable management of waste is to eliminate as far as possible the risk of pollution by pretreatment of waste deposited or depositing them in complete safety or in underground facilities, specially built for this, but that society contemporary Romania can not allow, particularly in economically, either by use of underground spaces resulting from the mining activities of various useful minerals.

Today suggested the need to calculate economic benefits by assessing the feasibility of all actions that can change the environment. Thus, a proper economic analysis can only be one that will take into account the environment.

This is a problem for both people and industry, and acceptable solution must be based on acquiring the already serious problems affecting quality of life and future can endanger life itself.

Using underground space it has been recognized as one of the most important ways of solving difficult problems of waste management.

In the face of immense pressure acting on the environment, using underground is a safe and most often only economically, given a correct design, safeguard the environment.

It must however be borne in mind that the underground facility may affect the environment both positively and negatively, so the role of design and studies to be carried out is precisely to maximize the positive effects and to eliminate or minimize the negative ones.

### **3. The direct benefits on the underground space**

Using underground space, in compliance with its copy of the surface results in a large number of direct benefits, most important being (Stefan, 2006):

- First point
- temperature is approximately constant in the ground which is an advantage for storage of certain products;
- moisture is easily controlled, and the quality of groundwater can be kept without difficulty;
- safety is excellent in terms of fire, flood, hurricane, big rain and snow;
- proliferation of insects and bacteria is better controlled than in the conventional storage of goods;
- damage and loss of production are considerably reduced material;
- land area is protected from pollution of the gas, liquid and solid. It also avoids aggression and destruction of forest land, flora and fauna.

Because of these advantages, today reported a large number of uses of underground spaces for storing: various documents, fuel oil, compressed air and other sources of energy, water, food and agricultural products, weapons and weapons sludge from waste treatment plants, spent fuel from nuclear power plants and atomic other radioactive waste, and municipal waste.

Also the underground space can be arranged to house museums, swimming halls, vaults of banks, research centres, oil refineries and various waste recycling centres, hydroelectric and atomic power plants. If atomic nuclear plant at Chernobyl was built underground as the vast majority of the damage caused by the explosion in April 1986 could have been avoided. Due to environmental constraints rising that are currently imposed on the various laws in most developed countries, they have been made in recent years, a large number of projects underground, while many others are under construction or stage conception.

There is now a general attention to these types of engineering solutions and many countries have begun to consider the underground space as a "resource" that must be treated and managed with care. Some developed countries have decided to evaluate this important resource in their territory by measuring underground spaces natural of abandoned mines or other excavation underground to develop large-scale projects in order to seek and implement new solutions for utilization of these resources.

Underground environment is not only an object of potential impact but also an element of moderation, which becomes clear when hosted arrangement aimed at protecting the environment such as water treatment plants or landfills.

Changes in the type and geographical distribution of the industry could lead to conflicts of land use: Also, changes in the environment, energy and operating costs in the industry may require new strategies and industrial policies.

Underground space can resolve some of these conflicts, and change long-term industrial strategy should consider the underground option. Underground disposal and storage projects are feasible, economically viable and can be clearly provides environmental benefits.

It therefore appears objectively as a detailed analysis, the environmental benefits related to the use of underground spaces are considered in economic terms, can often allow a change of perspective that compensates very high costs for the execution ground.

Practice environmental impact assessment must become an essential component in the design of all facilities to help address these enormous fears of humanity.

Benefits resulting from the achievement of underground facilities not only environmental benefits, but applies to:

- anyone directly involved in the work (client, user, company building);
- economic-social and people directly or indirectly involved due to the effects caused by construction work.

If achieving underground facilities between itself and the environment can be distinguished both positive interaction and negative, but it is important that the design work specific to succeed in harnessing all those positive interaction, to control and moderate the intensity of the negative in order to successfully use such arrangements and to eliminate the possibility of undesirable uncontrolled further, that through their action could cause damage to the environment.

Industrial activities could become technically, economically and legally feasible and environmentally advantageous placing them underground would be: deposits of oil, petroleum products and natural gas; deposits of industrial and consumer goods; cold storage of food; waste disposal mining, metallurgical, construction, household and radioactive; wastewater treatment systems.

Also the underground space could be used for recreational facilities such as museums and different places, but also for security deposit and religious facilities, while identifying appropriate sites and assessments correct.

### **4. Examples of the use of underground space**

#### *4.1. For residential use*

Uses the underground space as living space is probably the oldest of its use by people. Archaeological and anthropological research found many fossils in caves that serve as shelter in various parts of the world. Thus two of the remotest discoveries of cave dwellings are Qafzeh in Israel, dating back 92 000 years ago and Klasies River Mouth in South Africa where he was born the theory of anatomy, that people lived from 60 000 ÷ 120 000 years ago.

In many countries and regions of the world can give examples of historical settlements underground. The main reasons for the use of underground space for residential seem climate, there is a geologist and suitable topography, the need for protection against intruders and the existence of previous examples.

Settlements included significant underground dwellings carved in stone in Cappadocia in Turkey, which reached its peak in sec. X - XI of the Byzantine period. Two of the most famous underground cities are Kaymakli and Derinkuyu Anatolian which included civil engineering, ventilation shafts and tunnels connecting several kilometers excavated existing volcanic tuff.

In 1963, British archaeologist James Mellaart discovered a fresco now considered the oldest ever discovered landscaping work. Dating back 8000 ÷ 9000 years ago, the painting is also the oldest work of art made on a built area of people - a wall made of bricks plastered with mud. Fresca measuring 2.5 meters by two cones depicts a volcano erupts while being placed on a structure composed of multiple packs apparent. Soft volcanic tuff enough to allow a man to dig through it with a spoon. When exposed to air, however, the material is solidified. Historical evidence shows that around 700 before Christ people armed with iron tools digging into the ribs of Cappadocia to build their homes. Nobody knows how many underground cities in Cappadocia hide. Have so far been discovered eight cities and many smaller villages, but certainly there are others hiding underground. (\*\*\*)

#### *4.2. Derinkuyu - the largest and most mysterious underground city discovered*

One of the characteristics of the underground cities Cappadocia is set. It is known that in this region there are over one hundred underground settlements, many of which are open to the general public, however. Derinkuyu underground city is located in the eponymous town at a distance of 40 km of Goreme, Turkey. Originally built in soft volcanic rock in Cappadocia by Phrygians in the eighth and seventh century BC, the underground city Derinkuyu was expanded and developed in the Byzantine period. The city was connected with other underground cities through long tunnels of several kilometers.

To accommodate between 3000 and 50000 inhabitants. The complex has 11 levels. There are approximately 600 outlets by the city, hidden courtyards or under buildings. The city is about 85 m deep underground. It comprises the usual rooms found in underground cities, (churches, winery, living rooms and food storage, etc.). In addition, a large room that presents an arch, located in the 2<sup>nd</sup>, was a Christian missionary school rooms left were used for the study.

Derinkuyu city contains about 15 000 channels supplied fresh air ventilation in the depths of subterranean city. Vents that have a depth of 55 m were used as fountains.

The extensive network of passages, tunnels, corridors inclined linking family rooms and common areas where people puteu meet, work and pray. Level 3 and 4 are vertical scale. This passage leads to a cruciform church, which is the lowest.

Derinkuyu underground city was where the early Christians hid from the region, who escaped from persecution carried out in the Roman Empire.

One of the tunnels discovered by cavers is wide enough to allow simultaneous passage of three. Going along it, the scientists found that the tunnel connects to another underground city located at 10 kilometers away. Moreover, several findings suggest that at some point, all Cappadocia was linked to a hidden network of underground tunnels. Today, many people in the region use these tunnels to post cellars.

Archaeologist discovered that cities were lit with torches or oil lamps in, producing enough heat to maintain the temperature at a pleasant level. Moreover, it is likely that these underground cities have been used first as a winter shelter. In time, however, as the Hittites, Assyrians, Romans, Persians, Byzantines, Seljuk Turks and Christians found through these caves, each of these civilizations has deepened and extended them for another purpose: the defense. Moreover, scientists have concluded that the Seljuk Turks and Christians extended the original rooms, dug in prehistory, so as to allow the creation of underground stables for horses.

These civilizations were not the only ones considered cities as a good shelter underground war. In 1990, when the Gulf War was in full swing, the Turkish authorities have considered using underground shelter against bombs cities where conflict would be expanded regionally.

The underground city of Derinkuyu, underground stables housed below the floor feed. Below are found the communal kitchen equipped with furnaces earth below a ceiling of 3 meters with holes for ventilation. These bore holes specially drilled smoke tunnels, so that it reaches up to 2 kilometers away, to fool the opponents.

In Australia many mining towns have placed a number of housing and community buildings underground to escape the severe heat outside. These examples include Coober Pedy mining towns of White Cliffs and Andamooka.

In France and Spain sec. Twentieth use of underground spaces residential caves link to use as holiday homes, many of which are furnished to the highest contemporary standards.

The energy crisis of the 70<sup>s</sup> of the XX century generated a strong public interest in developed countries about the benefits of energy conservation in underground structures, so there have been some developments in the US multifamily along highway in Minneapolis.

#### **4.3. Recreational use**

Perhaps the most famous and widespread use of underground spaces for recreation is linked to the exploitation of caves for tourism, and the inclusion of tourism of the old me. Underground recreational facilities include sport facilities and community centers in many parts of the world. Types of facilities used include swimming pools, gyms, hockey halls and sports facilities with multiple purposes. Norway Gjøvik swimming pool and gym Kannusillanmaki sports center in Helsinki, Finland are examples of potential underground recreational facilities.

Georgetown University, Washington, a facility for sport has been extended under existing football field. In China, Hanzhou city has bars, a ballroom and multiple rooms designed for the amusement of children in the underground space and underground city of Hangzhou has a theater with 1800 seats, used and defensive end. Retretti concert hall in Finland is known around the world for acoustic performance achieved. In Japan, the underground space of the former limestone mines Ohya is a place often used for art exhibitions and numerous shows. In Poland mine in Wieliczka is famous for its use as a museum and concert hall. But the examples are many and countries in Central and Western Europe. In Romania are known recreational and health centers for curative value, Slanic Prahova salt mines and mine. These uses are specific underground voids created from solid salt extraction methods. Thus formed underground spaces are large and very large, they have constant temperature (12 °C) and humidity of approx. 50%.

#### **4.4. Use for urban development**

The most significant examples are present in Montreal and Toronto, consisting of large parking lots and underground pedestrian interconnected systems that allow movement in much of the area under the city without exposure to inclement weather or road traffic. They also contain shopping areas with the most fashionable stores.

Another example of an integrated urban development is complex underground Les Halles in Paris. The complex covers 100 000 m<sup>2</sup> and extends on four levels below ground, keeping the area a park surrounded by old and beautiful historical sites and architectural and includes subway, streets, parking lots, a great area for shopping, recreational facilities and a pool swimming. Japan has also a long history of development of underground shopping centers. Today more than 20 Japanese cities have shopping complexes and underground infrastructure services.

There is: using the library, offices, educational institutions, use for industrial facilities, use for military and civil defense facilities, religious use and the use of storage, see in (Georgescu and Ciolea, 2017).

### **5. The future underground**

In the XXI century, a growing group of visionary engineers and architects for increasingly more often to underground. But this time, why not escape religious persecution - their goal is to escape the crowds. (\*\*\*)

2018 will start construction of 9 billion a city underground, just below the famous canals of Amsterdam, which will include places for shopping, relaxing spaces and parking. Singapore, Toronto and Frankfurt plan also major underground development.

Not only will shop around underground, but Mexicans will live soon there.

A "sky-ground" on 65 levels proposed for Mexico City will descend about 300 meters below the main square. Inverted pyramid created by Bunker Arquitectura, will have a core of ten levels of glass that will send light to the 10 levels of housing, stores 10 levels and 35 levels of offices. Although not necessary to worry about miscreants Romans, living under the earth's surface has some distinct advantages.

"If you take into account phenomena such as natural disasters, where would you rather be: the 50<sup>th</sup> floor of a tall building or underground?", says Professor Samuel Ariaratnam engineer at the University of Arizona, one of the authors of a report by the National Academy of Sciences of the United States about the future of urban development underground, and if the surface climate change will create catastrophic conditions, then a shield of earth and stones, several meters thick, would be more desirable than a balcony with a view.

As recognizes Ariaratnam, down construction cost is higher than building up: "I think I see skyscrapers reverse in my lifetime," he says. But long term, the benefits begin to appear, and underground becomes a desirable place to live. "Look at hot and wet climates or the very cold. Who would want to hang out? "

One day, you could find and parks in the depths underground. There are proposals in the New York park "Lowline" in a huge area remained without use after scrapping a system of trams in 1948. The name is inspired by the High Line park, which was built on an abandoned rail system in western Manhattan. Mirrors and optical fibre cables will bring daylight into these caverns. Tubes reflectors will play a key role in this project by focusing sunlight above. These innovations will allow grass, bushes and even trees to grow on the surface of the Earth.

Existing underground developments have shown how the phenomena that we associate with the surface can be brought under the ground. Sanford Underground Research Centre - a complex of laboratories in South Dakota, which has levels from 90 metres depth to almost 2500 meters - the architects have worked with psychologists to try to make the environment as pleasant as possible. The screens show images of blue sky and ventilation systems create air flows to mimic the surface breezes. The designs are intended to prevent psychological problems.

But PhD. Raymond Sterling, a professor at Louisiana Tech and an expert in underground spaces, suggests that life at this level should be no problem. "Most people have no problem in using the London Underground or be in a room without windows during a concert", he says. "If people find a reason for this or if there are physical benefits to be underground, they can accept it."

## **6. Conclusions**

Underground space is an important resource whose use land began long before the birth of self-consciousness of man. Underground space in modern times began to be used widely overseas in the US first, then this type of use has grown in Western Europe and Japan. Spaces are underground link to geo-mechanical parameters identification, mining, favourable economic and political, which then serve to assess the feasibility of the proposed comparative technical schemes.

In Romania the lack of use of underground space facilities, consciously or using it enough, can be caused by: geology incorrect perception that the country is poor; absence of a strategic planning of the use of the subsurface; the insufficient funds allocated to this area; absence or insufficient knowledge of the advantages of the underground space; the absence of the necessary technology; tracking failure to respect the environment. The research in Romania in this direction should include the following objectives: presentation of the key points of technical considerations, geological and economic acceptance or rejection of the use of underground spaces; assessment of geological conditions, market and legislative framework and administrative process related to the use of underground space across the country.

In Romania analysis, particularly the following areas with direct implications in economic, social and environmental development should be prioritized: storage of natural gas and oil products; industrial warehouses and consumer goods; food warehouses; waste deposit; systems and storage elements and operation of wastewater treatment plants give industry and the household; storage of agricultural products; storage of raw materials and different materials.

In this regard should be given to re-use mines or excavations developed specially for this purpose, there is a large worldwide experience in the use of underground space even weak and intensely fractured rocks.

Underground space is recommended for residential, religious, recreational, urban development, library, offices, educational institutions, storage for industrial facilities, military facilities and civil defense.

In the process of using underground space must analyze many factors geological, geo-mechanics, mining and economic and solely by test results complexes on their decisions can be location undergrounds various social functions or industrial normally locates the surface.

## **References**

- Georgescu M., Ciolea D.I., *Utilizarea spațiilor subterane*, ISBN 978-973-741-544-8, Editura Universitas, Petroșani, (2017).
- Ștefan, O. - *Spațiul subteran, factor de salvagardare a mediului înconjurător*, Editura RISOPRINT, Cluj-Napoca, (2006).
- Wegner, W. - *Waste disposal in a German rock - salt mine*. E&Mj, April, pp. 32-35, (1993).
- \*\*\* <http://www.scienceworld.ro/viitorul-subteran-13057.html>

# Visual analysis of deformations from the quarry and inner dump steps from North Pesteana mining perimeter

Apostu Izabela-Maria<sup>a\*</sup>, Lazar Maria<sup>a</sup>, Faur Florin<sup>a</sup>

<sup>a</sup>University of Petroșani, Universitatii Street, no. 20, Petroșani 332006, Romania

---

## Abstract

Deformations and changes occurring in a rock mass, whether natural or anthropic, result from the geotechnical characteristics of the rocks and the influence of various external or internal factors. Under the influence of external factors, such as vibrations, overloads, the presence of groundwater or surface water, there results deformations and changes such as cracks, fissures, erosion and suffosion phenomenon, compaction, superficial or deep landslides etc. These types of deformations and changes signal the possibility of occurrence of negative geotechnical phenomena, such as landslides, which endanger the safety of people and objectives in the zones of influence. Also, these changes can influence the stability of the individual steps and even of the systems of steps, which is why it is necessary to constantly monitor and evaluate the stability in order to carry out the safety of the working operations.

In this paper, a visual analysis is performed in order to identify deformations occurring in the North Pesteana mining perimeter and to highlight the possible problems that may arise in terms of stability of the quarries and the safety of the employees and objectives of the areas of influence.

*Keywords:* visual analysis, deformations, landslide, quarry, inner dump, stability;

---

## 1. Introduction. The importance of visual analysis in slopes stability

The visual analysis of the deformations and changes occurring in a rock mass/rock deposit is an important step in the land stability assessment activity. Based on this, areas with potential risk are identified deformations, changes, possible causes and other related effects are highlighted.

The presence of discontinuities, such as fissure, cracks, fissures, stratification, etc., and changes resulting from surface erosion, suffosion or sliding phenomena, affect the strength characteristics of rocks and, implicitly, massifs of rocks (Rotunjanu, 2005).

Unlike faults that are large-scale tectonic discontinuities, cracks and fissures are small-scale discontinuities. As an extension they may vary from a few centimeters to tens of meters and may have an opening up to a few tens of centimeters. Cracks and fissures can cause the massive fragmentation of the masses and reduce the resistance of rocks and rock massifs (Rotunjanu, 2005).

Deformations and changes occurring in a massive of rocks are the result of alteration of the rocks understood as worsening of geotechnical characteristics under the influence of external or internal factors.

There are two types of alterations: superficial and deep. This paper focuses on the physical alteration of rock or its disintegration over time under the influence of various external or internal factors.

Surface alteration affects the rocks that constitute the superficial layer of rocks and is manifested by the permanent influence of external and internal factors: water, air, climate, organisms and gravity. Unlike this, the deep alteration is manifested under the action of the tectonic forces. The tectonics and micro tectonics of rock massifs are one of the main causes of landslides as a result of the reduction of the strength of the rock massive (Rotunjanu, 2005).

---

\* Corresponding author. Tel.: +4-072-874-0003.  
E-mail address: izabelamaria.nyari@yahoo.com .



Erosion is the dislocation and entrainment of material on land surfaces. Erosion can be pluvial or windy and manifest, as the name says, under the action of waters or wind, plus the influence of gravity. Rainwater erosion is the main form of erosion that is emphasized in the present case, since surface water leakage, depending on local conditions (rainfall, infiltration capacity, slope angle, water flow speed etc.) can determine the appearance of gullies (up to 30 cm deep) and small to large ravines (with depths of up to several meters) (Lazăr, 2010). The appearance of gullies and ravines are considered as being the primary processes of the landslides (Lazăr et al., 2012).

Landslides are superficial or depth displacements of the rocks on the slopes of rocks massifs. Landslides are the most frequent and dangerous forms of degradation of rock massifs and, most of the time, are signaled by the deformations and changes described in this paper.

Therefore, the first part of the paper shows the importance of performing visual analyzes, which is why a case study for the mining perimeter of North Pesteana quarry was carried out.

## 2. Location of the objective

The perimeter of North Pesteana quarry is administratively owned by Gorj County, being located within the Urdari and Balteni communes. The North Pesteana quarry was opened in the area where the Jiu River bedside existed prior to its regularization, and includes the Jiu meadow about 2 km wide, with odds of  $+137 \text{ m} \div +155 \text{ m}$ , inclined to the east, towards the Jiu river bed and to the south.

In the mining perimeter of North Pesteana quarry, both excavation and sterile dumping are carried out in 4 steps.

Taking into account that the mining perimeter is still in operation (for the next 6 years), this indicates that with the advancement of the working front and extension of the inner dump, there will always be new deformations and changes within the perimeter that may favor the occurrence of negative geotechnical phenomena.

## 3. Research and site observations

In order to be able to characterize the technical state of the internal dump and the in situ steps of the North Pesteana quarry, several field visits were carried out between April 2017 and June 2018. At the same time, these visits were aimed at collecting data and information on the geometrical and geotechnical characteristics of the rocks in the perimeter, the eventual sliding (superficial or profound) phenomena that occurred over time and their causes. (Apostu, 2018)

As a result of the visual analyzes carried out, and also on the basis of the information received, regarding the technical state of the quarry and of the inner dump, we will continue to list a number of observed aspects.

As a result of periods of excessive precipitation and of the periods of snow melting, there were some superficial landslides both on the in-situ slopes (Fig. 1.a) and on the inner dump slopes. The reason for these slides is the increase of the humidity of the rocks and, implicitly, of the volumetric weight, which leads to a decrease of the stability reserve.

Numerous erosion zones have been highlighted - generally, gullies (Fig. 1.b), so small ditches - formed as a result of the superficial water flow.

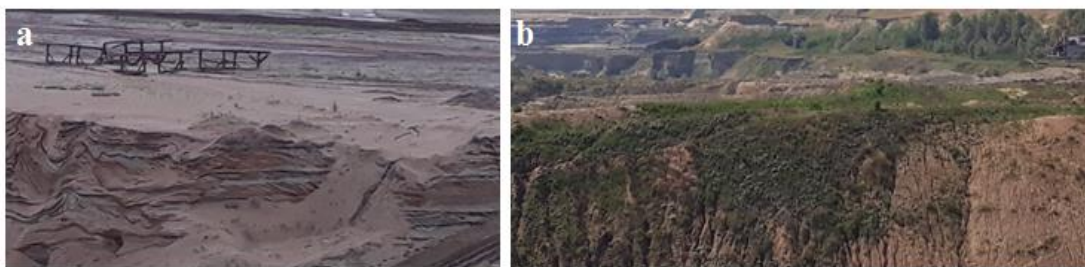


Fig. 1. (a) Superficial landslide on in-situ slope; (b) Gullies on inner dump slope;

As a result of the fact that the dewatering of the aquifer formations is realized naturally through the slopes of the quarry, the sufosis phenomenon was manifested, which led to the occurrence of sufosis zones on the slopes of the steps I (Fig. 2.a) and II. In the case of natural drainage of groundwater, there is continuous entrainment of the fine particles of rocks, which leads to the occurrence of these sufosis zones, basically underground gaps, of different dimensions and at different depths.

As a result of erosion by sufosis, depending on the depth at which the underground gap is formed and its size, can cause collapse of the rocks as a result of loss of rock stability from the roof of the gap.

Recently (at the beginning of 2018), on the eastern slope of the quarry there was a landslide, which affected the structure of the road that serves the mining perimeter (Fig. 2.b). The causes of this landslide were the abundant precipitation and the major infiltrations from the Jiu River.

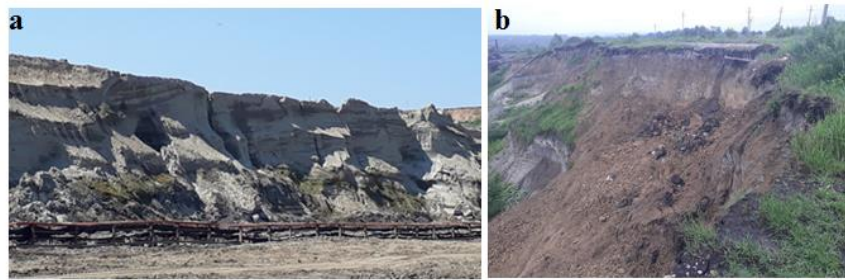


Fig. 2. (a) Sufosis zones on the first step of the quarry; (b) Landslide on the eastern slope of the quarry;

On the berms of the inner dump steps there were fissures and tension cracks (Fig. 3). Although these changes can be attributed to longer periods without rainfall, they generally signal the possibility of occurrence of the landslides, so it is recommended to follow these types of changes.



Fig. 3. Cracks on the berm of second step of the inner dump

Analyzing the situation plans, it has been observed that there are some differences between the projected geometry and the existing one, both in the steps of the inner dump and in the steps of the quarry. These differences generally occur at the slope angles and less at the height of the steps.

The values of the slope angles exceed the maximum values established in the project of  $18 - 27^\circ$  for the individual slopes of the dump, respectively  $4^\circ$  for the individual slopes of the quarry. It has been observed that sterile material is deposited in the dump on a natural slope angle, the value of which varies depending on the nature of the rock, reaching in many cases up to  $45 - 50^\circ$  (Fig. 4.a). As a result of the applied methods of exploitation and of the used equipment, the slope angle for the pitches reaches values of up to  $60 - 75^\circ$  or even higher (Fig. 4.b). It was found from one visit to another that the practice of reducing the inclination of the slopes is not applied, most probably on the fact that the working front, respectively the inner dump, is advancing continuously, so the steps with this geometry have short service life.



Fig. 4. Inclination of the slopes of the quarry and inner dump during the exploitation period; (a) Inner dump; (b) Quarry

It has been noticed that with the advancement of work fronts and the expansion of the inner dump, these deformations are remedied, but new changes arise that signal the reduction of the stability reserve and the possibility of occurrence of negative geotechnical phenomena under the continuous influence of external and internal factors.

#### 4. Measures to reduce the risk of landslide

Generally, these deformations and changes can't be prevented. As these cause the worsening of geotechnical characteristics of the rocks and signal the possibility of occurrence of negative geotechnical phenomena such as landslides, it is recommended to apply local measures to increase the resistance of rocks after their occurrence. Some of the measures that can be recommended for the North Pesteană quarry are:

- removal of gullies, ravines, fissures and cracks by material filling, leveling and compacting;
- proper management of groundwater and surface water;

- applying measures to reduce the amount of infiltrated water from the Jiu River to North Pesteana quarry by reducing the permeability of the right bank of the Jiu River;
- reducing the amount of water that drains naturally through the slopes of the quarry or reducing the rate of infiltration by increasing the flow of dewatering in order to prevent the phenomenon of sufosis;
- respecting the projected values of the geometrical elements of the quarry and inner dump steps. Failure to comply with the projected values may favor the occurrence of negative geotechnical phenomena.
- performing visual and geotechnical analyzes, where appropriate, and intervening as quickly as possible to prevent these phenomena from occurring on a larger scale.

According to the literature, the determination of the contours of the working slopes and of the final slopes must take into account a number of criteria, such as the economic and social importance of the objective and the time of their stagnation. Thus, for small service times, such as for working slopes in a mining perimeter, lower stability factors are acceptable, on the grounds that they are remedied as work advances, but for very long service life times, for the definitive slopes, the value of the stability reserve must be high. (Fodor, 1980; Rotunjanu, 2005)

## 5. Conclusions

The visual analysis allows the highlighting of the deformations and changes that may indicate the possibility of occurrence of negative geotechnical phenomena. Based on the visual analysis, in the perimeter of the North Pesteana quarry, there were identified erosion and sufosis zones, fissures and cracks, superficial landslides that did not affect the overall stability, these modifications being corrected as the work front advanced, but also a larger sliding in early 2018 on the eastern slope of the quarry that affected the structure of the road that serves the mining perimeter.

So far, the deformations and changes occurring on the steps of the quarry and the inner dump of North Pesteana mining perimeter did not affect the overall stability of the quarry or the inner dump, except for the landslide from the eastern slope of the quarry, but they may endanger the stability of the individual steps.

Generally, signs of erosion are the gullies, ditches of small dimensions. Also, the sufosis areas were of small and medium sizes, and did not affect the mining works or the stability of the career steps, but they could seriously jeopardize the safety of employees as a result of rock falls. Fortunately, during the observation period, no such event were recorded. Given the short service life time of the quarry steps, these types of changes are remedied as the exploitation works advance. Given the fact that with the advancement of the work fronts new deformations and changes occur, it is recommended to continuously perform visual and geotechnical analyzes, where appropriate, and to intervene as quickly as possible to prevent these phenomena from occurring on a larger scale.

Considering the behavior of the rocks from the quarry and inner dump steps within the North Pesteana mining perimeter under the influence of the external or internal factors, it is recommended to pay close attention and adequate intervention for the case of definitive slopes of the quarry, that have a much longer service life time than working steps, for decades, to increase the stability reserve and the degree of safety of the objectives in the areas of influence.

## References

- Apostu (Nyari), I.-M., *Determination of the geotechnical characteristics of the rocks from the definitive slopes of the remaining gap of the North Pesteana quarry and assessment of the stability conditions* (in Romanian), Research report no. 3, Petroșani, (2018).
- Fodor, D., *Open-pit mining exploitation* (in Romanian), Didactical and Pedagogical Publishing House, Bucharest, (1980).
- Lazăr, M., *Rehabilitation of degraded lands* (in Romanian), Universitas Publishing House, ISBN 978-973-741-161-7, Petroșani, (2010).
- Lazăr, M., Faur, F., Dunca, E., Ciolea, D.I., Landslides Occurred in Bujorascu Valley Dump and Stability Improvement Solutions, *Environmental Engineering and Management Journal (EEMJ)*, Vol. 11, Issue 7, pp. 1361-1366, (2012).
- Rotunjanu, I., *Slopes stability* (in Romanian), Infomin Publishing House, Deva, (2005).
- \*\*\*, *Report on environmental impact study, continuation of mining works in the license area for Peșteana Mining Quarry Unit - the North Peșteana quarry proposed to be located in the outbuilding/urban area of the Urdari, Bălteni and Ploșoru communes* (in Romanian), S.C. - Institute of Scientific Research, Technological Engineering and Lignite Mine Designing - S.A. Craiova, Gorj County, (2012).

# Quality improvement of switching parameters at switching with DC hybrid breaker

Titu Niculescu<sup>a\*</sup>, Dragos Pasculescu<sup>a</sup>

<sup>a</sup>University of Petrosani, 20 Universitatii street, Petroșani, Romania

## Abstract

The paper presents a modern method of improving the switching quality with hybrid DC switches by using a method for extinguishing the electric arc that emerges among the contacts of a direct current breaker. The method consists in using a LC type extinguishing circuit, which must be optimally dimensioned. From this point of view, a theoretical analysis of the phenomena that appear immediately after disconnecting the charge is presented, specific diagrams being presented. With their help, the elements of the extinguishing group can be dimensioned. In the second part of the paper, an analysis of the circuit commutation process is made by decomposing the process in particular processes that take place at different time sequences. For each interval it is conceived a model of numerical simulation in MATLAB-SIMULINK environment, which integrate the characteristic differential equations and draws the variation curves of the voltage on the condenser and of the oscillating current from the circuit.

**Keywords:** differential equation; electric arc; hybrid breaker; simulation; switching quality; zero current.

## 1. Introduction

In the hybrid breakers of direct current that don't have natural zero current, the situation of charge disconnection which is accompanied by the emergence of an electric arc inside the switcher and in time it can destroy its contacts, appears as a high problem (Atmaji, 2000), (Far and Jovicic, 2018). In these cases the commutation necessitates additional circuits that are parallel connected over the main breaker. The basic idea is to produce an injection of counter current which opposes the current of arc, therefore being produced a null resulting current through the main breaker (Bartosik, 1997), (Robbins, 1995). The effect of this zero current is the extinguishing of the arc among the contacts of the breaker.

The electric scheme of the basic circuit for the commutation of the charge in direct current is presented in Fig.1:

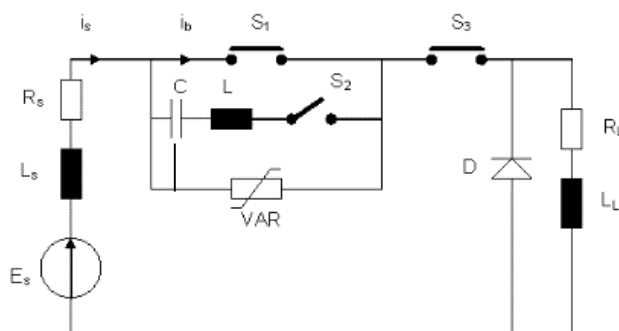


Fig.1 The electric scheme of the commutation circuit

The source of continuous voltage  $E_s$  that has the internal parameters  $R_s$  and  $L_s$  is connected in series with the main breaker  $S_1$ , with the electrical separator  $S_3$  and with the electric charge of parameters  $R_L$  and  $L_L$ . In parallel with the main breaker an auxiliary circuit is connected, consisting of a condenser  $C$ , a coil  $L$  and an auxiliary switch  $S_2$ , which usually

\* Corresponding author. Tel. +4-072-392-2072.  
E-mail address: niculescu\_titu@yahoo.com.

is a semiconductor (thyristor). The varistor VAR limits the overvoltages from the terminals of the breaker and the suppressor diode D takes the current when its slope is negative.

For extinguishing the arc in the main breaker  $S_1$ , the auxiliary switch  $S_2$  is immediately closed after the disconnection.

The energy stored in the condenser C taken from the source  $E_s$ , is released and generates a current that opposes the source current, resulting a zero current through the contacts of the main breaker.

The condenser C together with the coil L form an oscillating circuit that will produce a second zero current through the main breaker, in case the arc didn't extinguish itself on the first zero current. After the extinguishment of the arc (Pasculescu et al. 2017a), (Pasculescu et al., 2017b), the condenser C is charged again from the source  $E_s$  being prepared for a new commutation manoeuvre of the circuit (Benouar, 1994), (Das, 1997).

## 2. Analysis of the arc extinguishing process

If we mark  $U_{1c}$  the equivalent continuous voltage of the extinguishing circuit and its equivalent resistance R, the differential equation of the voltages is given by the relation (1):

$$LC \frac{d^2 u_c(t)}{dt^2} + RC \frac{du_c(t)}{dt} + u_c(t) = U_{1c} \quad (1)$$

From where the capacitive current:

$$i_c(t) = C \frac{du_c(t)}{dt} \quad (2)$$

Based on the equations (1) and (2), the numerical simulation scheme was conceived in MATLAB-SIMULINK (Ghinea and Firteanu, 2000), (Yang et al., 2017), (Zhang et al., 2017), which draws the arc current through the main breaker  $S_1$  (Fig.2).

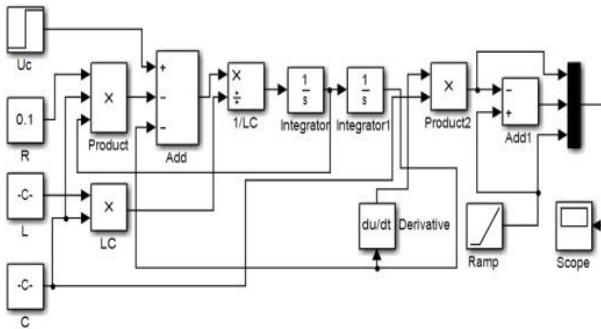


Fig.2 The numerical simulation scheme of the arc current

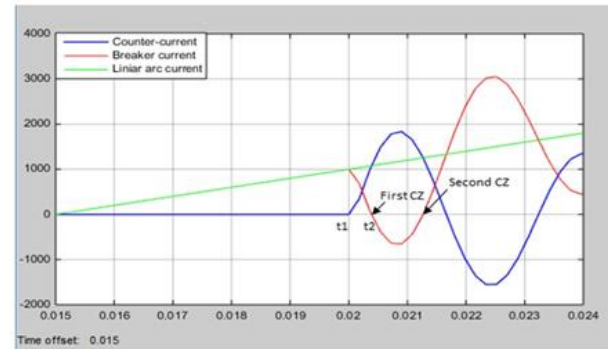


Fig.3 The diagram of the currents through the main breaker

The simulation scheme from Fig.2 generates the MATLAB diagram of the currents that appear in the commutation system (Fig.3). As it can be seen from the scheme, at the moment  $t_1$ , (related to the disconnection moment), the current reaches the value  $i_{t1}$  when the voltage on the condenser C has the value  $U_{C0}$ .

On this moment  $t_1$ , an injection of counter current emerges in opposition with  $i_s$ , so that the current through the contacts of the main breaker begins to decrease (Franck, 2011), (Shan et al., 2017). At the moment  $t_2$  it becomes zero and the voltage drop on the condenser decreases to the value  $U_{C2}$ .

## 3. The analysis of the commutation processes

For the study of the commutation process, the circuit from Fig.4 was used.

The process of interrupting the current can be divided in three time intervals, where each interval is described by a differential equation.

These differential equations can be integrated in the MATLAB-SIMULINK environment, which allows the drawing of the current variation curves and of the voltage on the condenser.

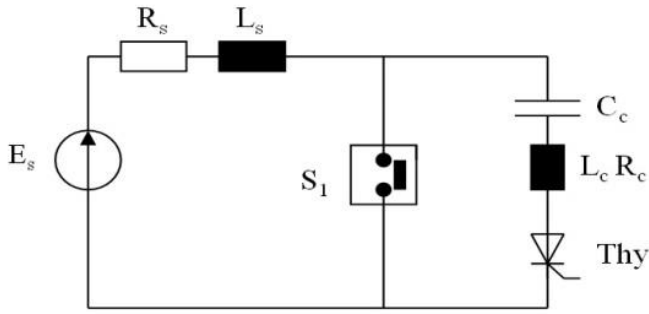


Fig.4 The electric scheme of the commuted circuit

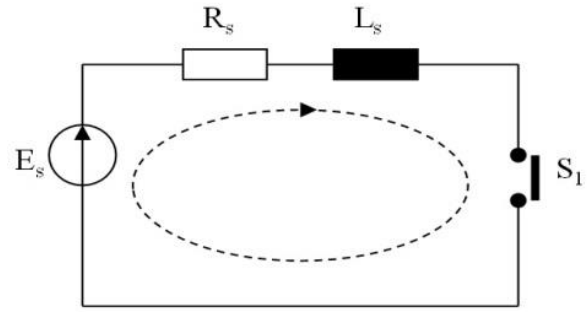


Fig. 5 The flow of the current in the interval [0-t1]

The following moments of time were taken into account.

- $t_1$  – the time after which  $S_2$  closes and the oscillating process begins;
- $t_2$  – the time after which the first zero current appears through the main breaker  $S_1$ ;
- $t_3$  – the time after which the source current becomes zero and the condenser  $C$  is maximum charged.

### 3.1 The time interval $[0 - t_1]$

In this time interval the current of the source goes through a loop  $E_s$  like Fig.5, and it is described by the differential equation (3):

$$L_s \frac{di_s}{dt} + R_s i_s = E_s \quad (3)$$

If the initial conditions for this interval are taken into account, the current through the circuit has the expression:

$$i_s(t) = \frac{E_s}{R_s} \left(1 - e^{-\frac{t}{T}}\right) \quad (4)$$

where  $T = L_s/R_s$  is the time constant of the circuit. Its variation is an exponential function.

### 3.2 The time interval $[t_1 - t_2]$

At the moment  $t_1$  the oscillation in the extinguishing circuit begins and the countercurrent appears through the main breaker.

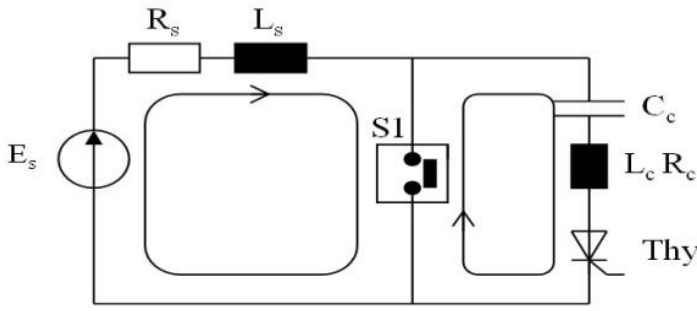
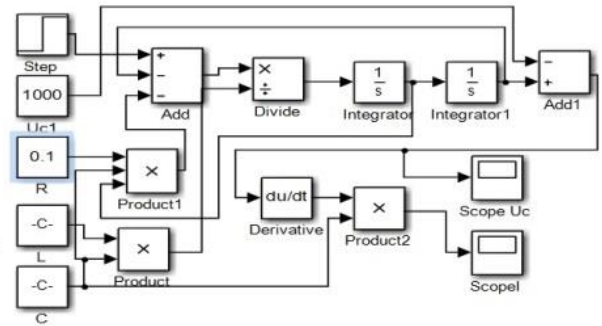
The voltage on the condenser that belongs to the extinguishing circuit is described by a differential equation of second order:

$$LC \frac{d^2 u_c}{dt^2} + RC \frac{du_c}{dt} + u_c = U_{c1} \quad (5)$$

where  $U_{c1}$  is the voltage on the condenser  $C_c$  at the moment  $t_1$

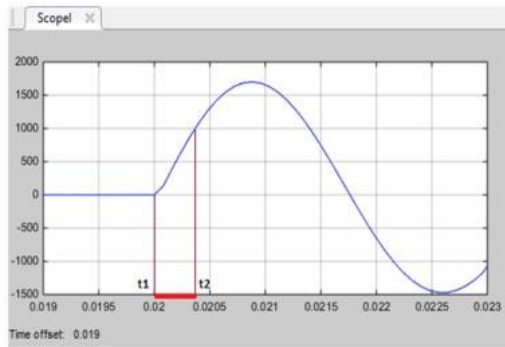
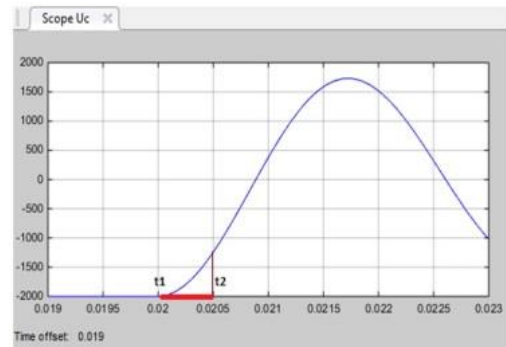
The differential equation (5) is integrated in the MATLAB-SIMULINK environment. The scheme of numerical simulation which draws the voltage variation (Koldby and Hyttinen, 2009), (Vincens et al. 2017) on the condenser and the current through the extinguishing circuit is presented in Fig.7.




 Fig.6 The flow of the current in the interval  $[t_1-t_2]$ 

 Fig.7 SIMULINK model of the oscillating and of the current through the condenser in the interval  $[t_1-t_2]$ 

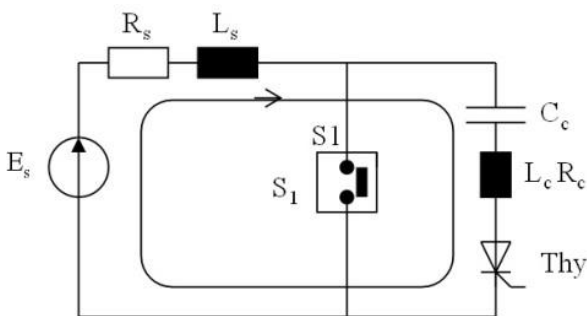
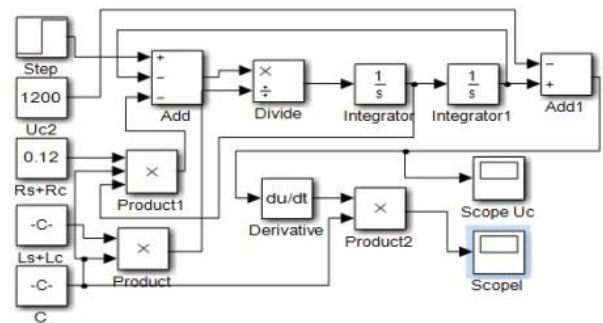
This model generates the following diagrams: (Fig.8 and Fig.9):

At the moment  $t_2$  the current through the main breaker  $S_1$  becomes zero and the voltage at the terminals of the condenser reaches the value  $U_{c2}$ .


 Fig.8 The variation of the current in the interval  $[t_1-t_2]$ 

 Fig.9 The variation of the voltage on the condenser in the interval  $[t_1-t_2]$ 

### 3.3 The time interval $[t_2 - t_3]$

In this interval, the current of the source becomes equal with the current through the condenser. The voltage on the condenser at the initial moment is  $U_{c2}$  and the current  $I_{t2}$ . After switching on the main breaker, the circulation of the current takes place as it is shown in Fig.10:


 Fig.10 The circulation of the current in the interval  $[t_2-t_3]$ 

 Fig.11 The SIMULINK model of the oscillating voltage and of the current through the condenser in the interval  $[t_2-t_3]$ 

The voltage on the condenser of the extinguishing circuit is described by a differential equation of second order:

$$C_c(L_s + L_c) \frac{d^2 u_c}{dt^2} + C_c(R_s + R_c) \frac{du_c}{dt} + u_c = U_{c2}$$

(6)



The differential equation (6) is integrated using the same environment of numerical simulation. The simulation model (Pasulescu et al., 2014) that generates the variation of the voltage on the condenser and the variation of the current through the extinguishing circuit is presented in Fig.11.

The SIMULINK model previously presented leads to obtaining the following diagrams:

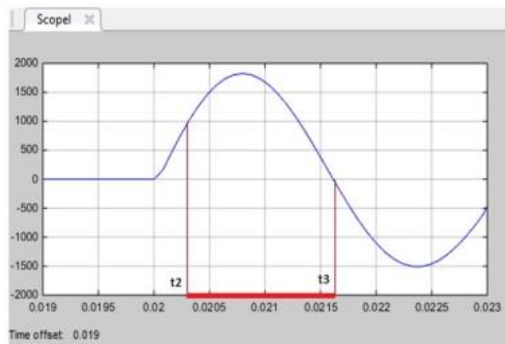


Fig.12 The variation of the current in the interval  $[t_2-t_3]$

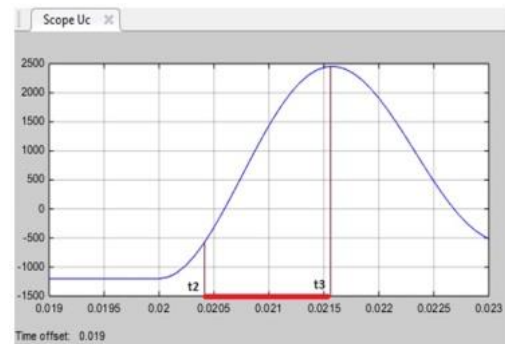


Fig.13 The variation of the voltage on the condenser in the interval  $[t_2-t_3]$

At the moment  $t_3$  the current of the sources reaches the value zero, while the condenser  $C_c$  is completely charged, as it can be seen in Fig.13.

#### 4. Conclusions

The quality of switching with DC hybrid breakers is dependent on the correct sizing of the arc extinguishing group that appears between its contacts.

This is possible through a detailed analysis of the switching phenomenon and by an appropriate choice of the values of the elements of the extinguishing group using the relations and diagrams obtained and presented in the paper.

The commutation manoeuvre of the charge can take place in the situations in which  $S_2$  is either with unidirectional conduction or with bidirectional conduction.

If the auxiliary switch  $S_2$  is chosen to be a unidirectional (thyristor), the counter-current that emerges in the resonant circuit LC can produce two zero currents, in which case there are two opportunities to extinguish the arc.

Another method of interrupting the charge current assumes the use of a bidirectional switcher. In this case, having commutated the current of the source, the oscillations of the current continue on the duration of some time periods until the final voltage on the condenser becomes equal with the voltage of the source. During the oscillations the energy is transferred between the source and the circuit LC. Using a vacuum breaker is an excellent method for interrupting the charge current.

Depending on the value of the commutation current, an adequate switch can be chosen from the available power semiconductors. The devices with static interruption are frequently vulnerable at the rising of the current slope. The switch must be able to resist the countercurrents when connected and the overvoltage when disconnected. In principle, the power semiconductors allowed that the high current to be commutated by lowering its frequency. When the frequencies of the circuit LC are high, a good method for interrupting the charge current consists of using the vacuum breakers.

#### References

- Atmaji, A., *Direct Current Hybrid Breakers*, Data Library Technical University Eindhoven, (2000).
- Bartosik, M., Progress in D.C. breaking, *8th International Conference Switching Arc Phenomena*, Vol. 2, pp. 25-41, Lodz, Poland, (1997).
- Benouar, M., Pyrotechnique circuit interrupter for the protection of electrical systems, *IEEE Transactions on Power Apparatus and Systems*, Vol. Pas-103, No. 8, (1984).
- Das, J.C., Limitations of fault current limiters for expansion of electrical distribution systems, *IEEE Transactions on Industry Applications*, Vol. 33, No.4, (1997).
- Far, A.J., Jovicic, D., Design, modeling and control of hybrid DC circuit breaker based on fast thyristors, *IEEE Transactions on Power Delivery*, Vol. 33, Issue 2, pp. 919-927, (2018).
- Franck, C.M., HVDC Circuit Breakers: A Review Identifying Future Research Needs, *IEEE Transactions on Power Delivery*, Vol. 26, pp. 998-1007, (2011).
- Ghinea, M., Firteanu, V., *Matlab- numerical calculation – graphics – applications*, (in Romanian), Teora publishing House, Bucharest, Romania, (2000).
- Koldby, E., Hyttinen, M., Challenges on the Road to an Offshore HVDC Grid, *Nordic Wind Power Conference*, Bornholm, (2009).

- Pasculescu, V.M., Vlasin, N.I., Florea, D., Suvar, M.C., *Improving the quality of the process for selecting electrical equipment intended to be used in potentially explosive atmospheres*, Quality-Access To Success, Vol. 18, S1, pp. 97-102, (2017).
- Pasculescu, V.M., Vlasin, N.I., Suvar, M.C., Lupu, C., *Decision support system for managing electrical equipment used in hazardous atmospheres*, Environmental Engineering and Management Journal, Vol. 16, Issue 6, pp. 1323-1330, (2017).
- Pasculescu, V.M., Radu, S.M., Ghicioi, E., Pasculescu, D., Niculescu, T., Assessing the safety level of technical equipment operating in potentially explosive atmospheres by using computer modelling, *14th International Multidisciplinary Scientific Geoconference (SGEM), Geoconference on Informatics, Geoinformatics and Remote Sensing*, Vol. I, pp. 43-50, Albena, Bulgaria, (2014).
- Robbins, T., Circuit-breaker model for over-current protection simulation of DC distribution systems, *17th International Telecommunications Energy Conference (Intelec 95)*, The Hague, Netherlands, pp. 628-631, (1995)
- Shan, Y.H., Lim, T.C., Finney, S.J., Guang, W.X., Williams, B.W., Holliday, D., Ding, X., Cascaded commutation circuit for a hybrid DC breaker with dynamic control on fault current and DC breaker voltage, *IET Power Electronics*, Vol. 10, Issue 6, pp. 676-686, (2017).
- Yang, B.J., He, Z.Y., Ma, H.Y., Wang, H.F., Lu, Y., Qiu, P., Huang, P.X., Fault isolation characteristics of the hybrid DC circuit breaker, *IEEE Conference on Energy Internet and Energy System Integration (EI2)*, Beijing, Peoples R China, (2017).
- Zhang, B., Kong, J.J., Chen, J., Zhang, Z., Chen, E.D., Xiang, Y.T., Simulation and fault analysis of DC breaker in HVDC converter station, *2nd International Conference on Power and Renewable Energy (ICPRE)*, pp. 261-265, (2017).

# Management of the optimal operating states of electrical distribution stations

Leon Pana<sup>a\*</sup>, Dragos Pasculescu<sup>a</sup>, Florentiu Deliu<sup>b</sup>

<sup>a</sup>University of Petrosani, 20 Universitatii street, Petrosani, Romania

<sup>b</sup>„Mircea cel Batran” Naval Academy, Fulgerului Street, no.1, 900218, Constanta, Romania

---

## Abstract

This paper presents the up-to-date methods employed of analytical evaluation of optimal power of electric stations within the framework of electric energy conversion and distribution stations or substations. Evaluation of optimal power of electrical transformers has been made on the basis of economically criterions, which to take in account the cost of transformers as well as power and energy damages.

*Keywords:* operating states; power transformer; loading coefficient; optimal power; electric stations.

---

## 1. Introduction

When designing the connection with power systems of the power supply distribution systems, the solving of the following problems is taken in account:

- Satisfying the mining consumers requests
- Ensuring the optimal degree of safety for each development stage (of the mining consumer area), of some simple and economic solutions, adapted on consumer categories and classes
- Adopting some modular and elastic schemes to allow, in any stage, the adaptation to the modern solutions which can intervene in the electro energetic installations, the possibility of power supplying for some unforeseen objectives (Pana, 2006).
- Adopting a flexible structure of the optimization criterion to allow the highlighting of some possible differential evolutions of the influence factors (Ionescu and Pop, 1998).

Generally speaking the distribution stations usually operate with a transformer in hot or cold reserve, and the one in operation rarely reach a charging of 50% $S_{nT}$ . The concerns regarding the optimization of the nominal power of the electric transformers and respectively for the optimization of the distribution stations configuration regarding the industrial consumers supplying, according to the absorbed power, are justified through the important energy savings that can be obtained in this regard (Pana, 2006), (Ionescu and Pop, 1998), (Ionescu and Baci, 1981), (Dusa and Vaida, 2001), (Ignat and Popovici, 2003), (Pasculescu et al. 2017a), (Pasculescu et al., 2017b).

## 2. Analysis of the configuration 2x100%

The operation of the electric transformers according to the chart of the optimal regime assumes establishing the number of the operating transformers and their charging, so that the total energy loss to be minimum.

In this situation, the problem of the connection or the disconnection of a transformer arises, at the variation of the total charge on the station, so that to permanently check the optimal functioning chart. The single line diagrams, frequently met for the electric stations, are presented in figure 1.

In order to perform the analyze, the following basic hypotheses are admitted: the nominal power of the transformers is the optimal one, the characteristics of the switchgear of the same type are identical and the momentary apparent absorbed power (S), expressed in kVA or MVA is considered to be variable in time (during a working day).

---

\* Corresponding author. +4-072-912-9138.  
E-mail address: leon\_pana@yahoo.com

The switchgear can be provided with an automatic reclosing system.

We mark with:

1. the status with only one power path in operation (passive reserve)
2. the status with both power paths in operation.

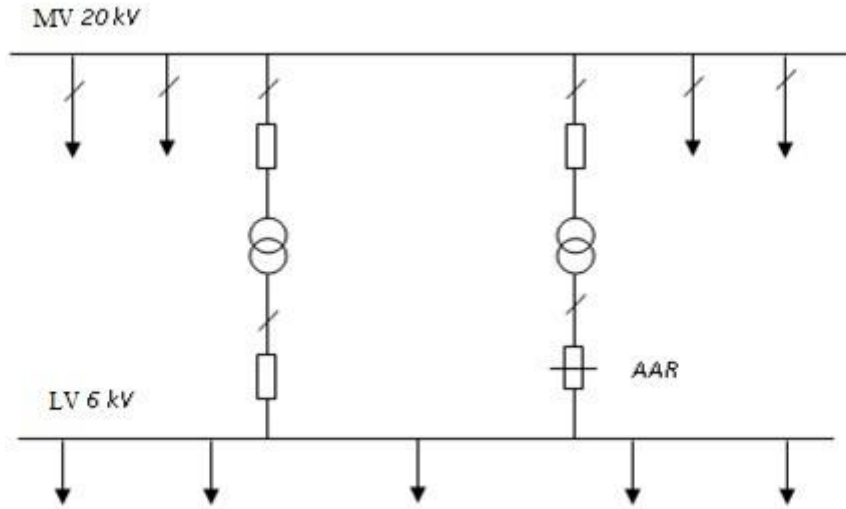


Fig.1 The single line diagram of the electrical distribution station, of MV/LV, (configuration type 2x100%)

### 3. The analytical model of calculation

We continue presenting the calculation relations for the absorbed power to which the commutation between the two states is required, according to the applied optimization criteria and the considered factors of influence.

Taking in account the two possible states, previously mentioned, and applying the criteria of the minimum loss of power, noting with:

$$\Delta P_{12} = \Delta P_1 - \Delta P_2 \quad (1)$$

the difference of the total losses of power in the transformers, expressed in kW, with reference to the two states, the following relations are achieved:

- If the losses of reactive power are neglected:

$$\Delta P_{12} = \frac{\Delta P_{kn}}{2} \cdot \left( \frac{S}{S_{nT}} \right)^2 - \Delta P_0$$

$$S = S_{nT} \cdot \sqrt{\frac{2 \cdot \Delta P_0}{\Delta P_{kn}}} \quad (2)$$

If also the losses of reactive power are considered:

$$\Delta P_{12} = \frac{1}{2} \cdot (\Delta P_{kn} + k_e \cdot \Delta Q_{kn}) \cdot \left( \frac{S}{S_{nT}} \right)^2 - (\Delta P_0 + k_e \cdot \Delta Q_0)$$

$$S = S_{nT} \cdot \sqrt{\frac{2 \cdot (\Delta P_0 + k_e \cdot \Delta Q_0)}{(\Delta P_{kn} + k_e \cdot \Delta Q_{kn})}} \quad (3)$$

The signification of the ratings that appear in the above relations is the following one:

$S_{nT}$	is the apparent nominal power of the transformer, in kVA
$\Delta P_0$	the losses of active power in iron (the losses of active power when idle) of the transformer, in kW
$\Delta P_{kn}$	the nominal losses of active power when operating in short circuit (the transformer operating at the nominal charge), in kW
$\Delta Q_0$	the losses of reactive power in iron or when idle, of the transformer, in kVAr
$\Delta Q_{kn}$	the nominal losses of reactive power when operating in short circuit (the transformer operating at the nominal charge), in kVAr
$k_e$	the electro energetic equivalent, expressed in kW/kVAr

The optimal or economic power to which the transformers commutation is justified, with reference to the two states, applying the criteria of the cost of the minimum losses of power and energy, is determined based on the relation:

$$\frac{1}{2} \cdot (\Delta P_{kn} + k_e \cdot \Delta Q_{kn}) \cdot \left(\frac{s}{s_{nT}}\right)^2 \cdot C_k - (\Delta P_0 + k_e \cdot \Delta Q_0) \cdot C_0 = 0 \quad (4)$$

in which:

$$\begin{aligned} C_0 &= C_p + C_w \cdot T_f \cdot T_{20} \\ C_k &= C_p + C_w \cdot \tau \cdot T_{20} \cdot m_r \end{aligned} \quad (5)$$

$C_0$  is the cost of the updated value of a unit of power loss in iron for  $n$  years running time, in €/kW  
 $C_k$  the cost in updated values of a unit of active power losses in short circuit and in the hypothesis of a  $r$  growth rate of the annual charge peak, in €/kW  
 $C_p$  the basic specific cost of the power installed in the power plants of equivalence, in updated values, in €/kW  
 $C_w$  the average specific cost on system of losses kilowatt hour calculated at the level of the HV/MV or MV/LV distribution station, in €/kWh  
 $m_r$  charge multiplier and has the expression:

$$m_r = \frac{1}{(1+a) \cdot T_n} \cdot \sum_{m=0}^{n-1} \frac{(1+r)^{2m}}{(1+a)^m} \quad (6)$$

in which:

$r$  is the growing rate of the annual charge peaks in that period, and  $a$  is the update rate. In case it is considered  $r = 0$  and  $n = 20$  years, respectively  $n=30$  years, the charge multiplier  $m_r=1$ ;  
 $\tau$  calculation duration of the annual technological power losses, in h/yr, of which value can be taken from the diagrams or can be calculated with the relation:

$$\begin{aligned} \tau &= T_{SM} \cdot \frac{10000 + T_{SM}}{27520 - T_{SM}} \\ \tau &= T_{SM} \cdot \frac{10000 + T_{SM}}{27520 - T_{SM}} \end{aligned} \quad (7)$$

$T_{SM}$  the use duration of the annual maximum apparent power, expressed in h/yr  
 $T_f$  the operating duration of the transformer, in h.

The optimal charging coefficient  $k_V$  for the annual charge peak is determined with the relation:

$$k_V = \frac{s_{ec}}{s_{nT}} \cdot \sqrt{\frac{2 \cdot (\Delta P_0 + k_e \cdot \Delta Q_0) \cdot C_0}{(\Delta P_{kn} + k_e \cdot \Delta Q_{kn}) \cdot C_k}} \quad (8)$$

Replacing the relations (5) in the relation (8), equation (9) is given by:

$$k_V = \frac{s_{ec}}{s_{nT}} \cdot \sqrt{\frac{2 \cdot (\Delta P_0 + k_e \cdot \Delta Q_0) \cdot (C_p + C_w \cdot T_f \cdot T_{20})}{(\Delta P_{kn} + k_e \cdot \Delta Q_{kn}) \cdot (C_p + C_w \cdot \tau \cdot m_r \cdot T_{20})}} \quad (9)$$

In figure 3 a, b, c, d, e, f and g presented below it can be seen that all the characteristics of the different values specific to the cost of the losses kilowatt hour  $C_w$  pass through a same point D (figure 3) in which the derivative:

$$\frac{dk_V}{dc_w} = 0 \quad (10)$$

The value of the intersection point ordinate, D (figure 3), is determined with the relation:

$$\tau_D = \frac{T_f}{m_r} \quad (11)$$

The value of the intersection point ordinate D corresponds to the specific cost of the energy losses  $C_w = 0$ .

With the growth of the specific cost of the energy losses  $C_w$ , the optimal degree of charging at the peak decreases or increases according to the number of hours of using the maximum charge  $T_{SM}$  is higher or lower than  $T_{max,D}$  calculated according to the relation presented below:

$$T_{\max.D} = 10^4 \sqrt{\frac{\tau_D}{8760}} - 1240 \quad (12)$$

Analogically to the case of the minimum cost of losses energy criteria applied for determining the optimal charging coefficient in the first year of operation of a transformer, in this case too, in the hypothesis of a minimum of the cost regarding the power and electricity losses, theoretical domain of variation of the optimal charge at the annual charge peak (figure 3 a, b, c, d, e, f and g) is limited by two characteristics.

$$k_{V1} = k_{VD} = \lim_{c_w \rightarrow 0} k_V = \sqrt{\frac{2 \cdot (\Delta P_0 + k_e \cdot \Delta Q_0)}{\Delta P_{kn} + k_e \cdot \Delta Q_{kn}}} \quad (13)$$

$$k_{V2} = \lim_{c_w \rightarrow \infty} k_V = \sqrt{\frac{2 \cdot (\Delta P_0 + k_e \cdot \Delta Q_0) \cdot T_f}{(\Delta P_{kn} + k_e \cdot \Delta Q_{kn}) \cdot \tau \cdot m_r}} \quad (14)$$

#### 4. Case study

The configuration of electric distribution station analyzed is presented in figure 2 and is provided with a double system of busbars to which cells are connected. The electric station is equipped with two transformers TTU-NL of 16 MVA, 20/6 kV through which the electricity distribution is performed and two transformers TTU-NL of 1000 kVA, 20/0.4 kV to supply the consumers. From the four transformers only two are in operation, the other two are in reserve. The transformers parameters and the results of the simulation are presented in table 1.

For the growth rate of the annual charge peaks  $r$ , respectively the duration of  $n$  years of the transformers operating same distribution station, the values of the charge multiplier  $m_r$  have a narrower range of variation. With the help of the relation (6), in which it was considered  $n=20$  years,  $a=0.01$  and for  $r = [0.02, 0.05]$ , it resulted  $m_r = [1.5, 1.53]$ .

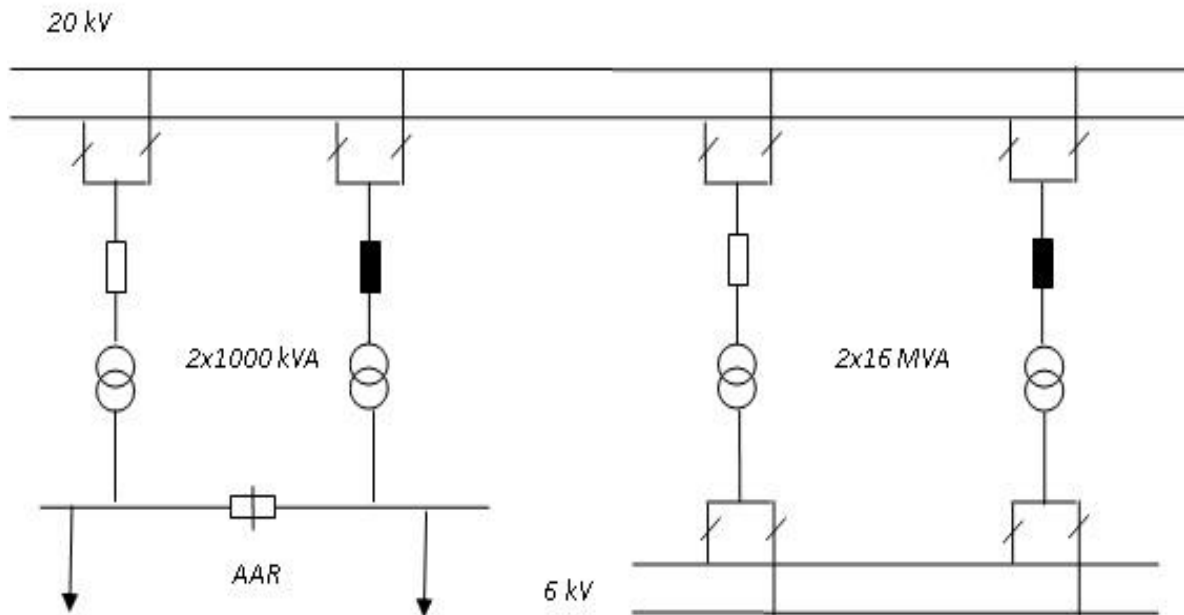
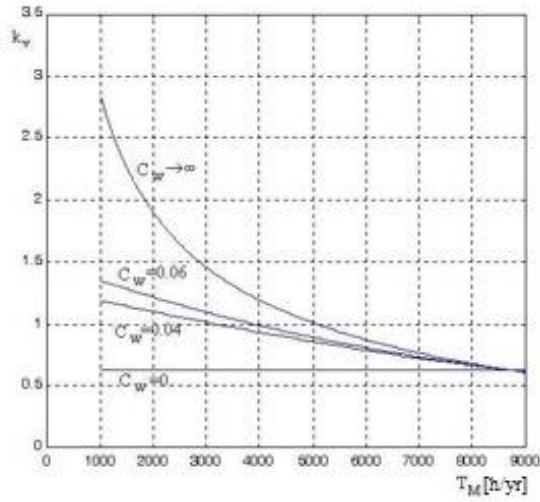


Fig. 2 Single line wiring diagram of the distribution station analyzed

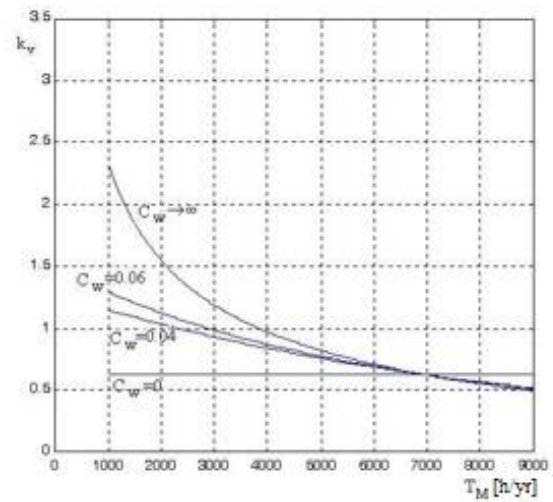
Table 1. The input data for the series of transformers type TTU-NL, of MV/LV

$S_{nT}$ [kVA]	$U_1/U_2$ [kV/kV]	$\Delta P_0$ [kW]	$\Delta P_k$ [kW]	$i_0$ [%]	$u_k$ [%]	$k_e$ [kW/kVAr]	$\Delta Q_0$ [kVAr]	$\Delta Q_k$ [kVAr]
1000	20/0.4	1.7	10.5	1.4	6	0.15	14	60
1600	20/0.4	2.2	14.960	1.4	6	0.15	22.4	96
16000	20/6	16.5	85	2.08	8.5	0.15	332.8	1360

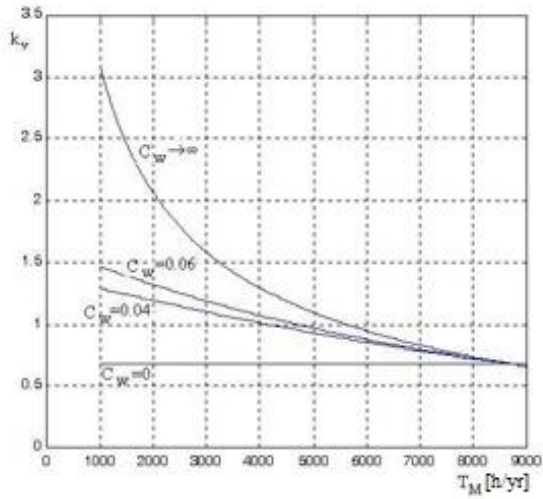
In figure 3 a, c, e ( $r=0$ ), b, d, f ( $r=0.02$ ) and g ( $r=0.05$ ) there are presented the values of the charging coefficients corresponding to the optimal operating states of the electric distribution stations of 20/6 kV analyzed had configuration presented in figure 2.



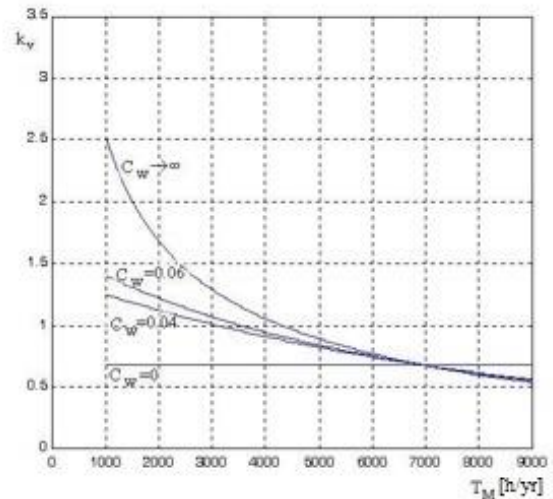
a)



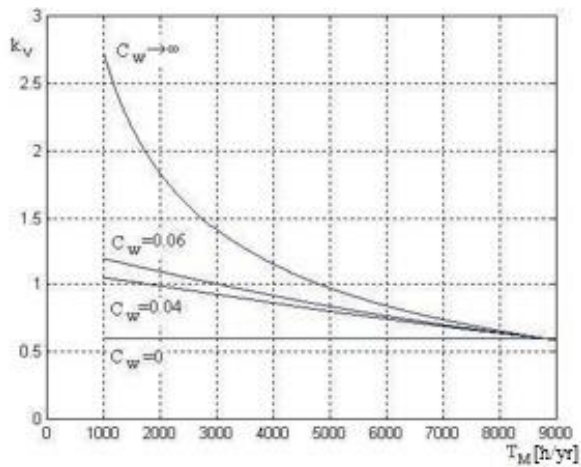
b)



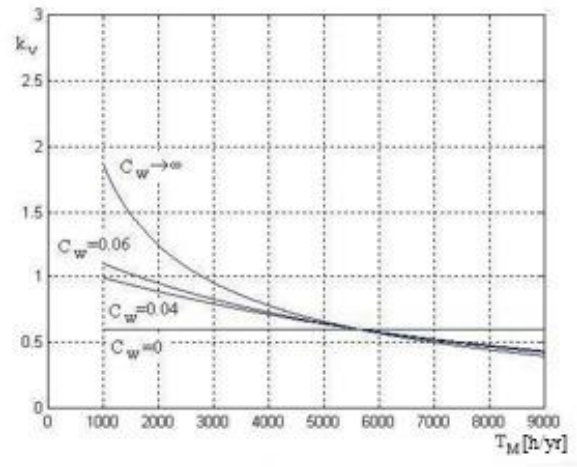
c)



d)

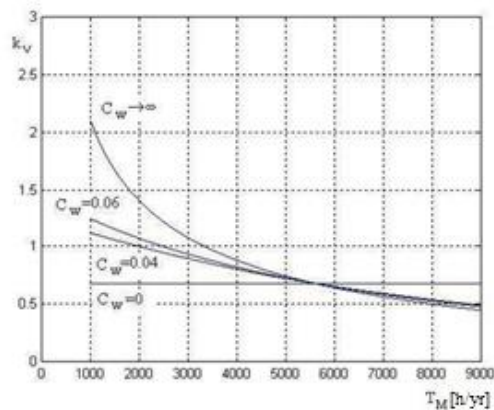


e)



f)





g)

Fig. 3 The values of the charging coefficients at the inferior limit corresponding to the optimal operating states of the electric stations, according to the time of use of the maximum annual charge, for different values of the kilowatt hour cost corresponding to the stages at which the electricity distribution is made and of the values of the charging growth coefficient

a)	2x1000 kVA, $r=0$	b)	2x1000 kVA, $r=0.02$	c)	2x16000 kVA, $r=0$
d)	2x16000 kVA, $r=0.02$	e)	2x1600 kVA, $r=0$	f)	2x1600 kVA, $r=0.02$
g)	2x16000 kVA, $r=0.05$				

In the case of the transformers, from the electric stations, operating in parallel, it is noticeable that with the growth of the coefficient  $r$ , the optimal charging coefficient at the annual charge peak also grows. In this case too it was demonstrated that if the charge is constant during a year, then  $r = 0$  and the losses time is equal with the operating time, meaning  $\tau = T_f = 8760$  h/yr. Analyzing the diagrams from the figure 3 a, b, c, d, e, f, g it results that the optimal value of the charging coefficient at the lower limit is in the range  $[0.52, 0.55]$ .

## 5. Conclusions

In conclusion, it results that in the electric distribution stations equipped with more transformers it is not economical to be used with all the transformers connected in parallel, irrespective of the electric charge and nor with only one at charges considered low, when these exceed the nominal power of the transformer.

The optimal operating regime in the case previously analyzed is the one in which the cost of the total power and energy losses (active and reactive) are minimum.

To obtain an optimal operating regime of the electric stations, it also must be determined the optimal power of the station, as follows:

- In normal operating regime at the maximum economically power, (minimum losses reported to the circulated energy).
- In emergency mode it will be taken account the reservation possibilities through the medium or low voltage networks that will be charged up to their thermal limit, the overcharge possibilities over the economical limit of a transformer in the case of failure in the neighbor station or of the second transformer from the same station.

The diagram of the transformation station presented in figure 3 has a transformer in reserve and an operating one, the one can in reserve, through automatics, replace (AAR – automatic reclosing system) the second transformer.

## References

- Dusa, V., Vaida, V., *Comanda si controlul functionarii retelelor electrice*, Editura Tehnica, Bucuresti, (2001).  
 Ignat, J., Popovici, C.G., *Rețele electrice de joasa tensiune*, Editura Matrix Rom, Bucuresti, (2003).  
 Ionescu, G.T., Baci, A., *Rețele electrice de distributie*, Editura Tehnica Bucuresti, (1981).  
 Ionescu, G.T., Pop, O., *Ingineria sistemelor de distributie a energiei electrice*, Editura Tehnica, Bucuresti, (1998).  
 Pana, L., *Tehnici de optimizare in sistemele electroenergetice miniere*, Editura Focus, Petrosani, (2006).  
 Pasculescu, V.M., Vlasin, N.I., Florea, D., Suvar, M.C., *Improving the quality of the process for selecting electrical equipment intended to be used in potentially explosive atmospheres*, Quality-Access To Success, Vol. 18, S1, pp. 97-102, (2017).  
 Pasculescu, V.M., Vlasin, N.I., Suvar, M.C., Lupu, C., *Decision support system for managing electrical equipment used in hazardous atmospheres*, Environmental Engineering and Management Journal, Vol. 16, Issue 6, pp. 1323-1330, (2017).

## Issues concerning the requirements for the achievement of a spark test apparatus simulator for linear circuits

Danut Grecea<sup>a\*</sup>, Sorin Burian<sup>a</sup>, Marius Darie<sup>a</sup>, Tiberiu Csaszar<sup>a</sup>, Cosmin Colda<sup>a</sup>,  
Adriana Andris<sup>a</sup>, Gabriela Pupazan<sup>a</sup>, Lucian Moldovan<sup>a</sup>

<sup>a</sup>National Institute for Research and Development in Mine Safety and Protection to Explosion - INSEMEX, 32-34 G-ral Vasile Milea Street, Petrosani, ROMANIA

---

### Abstract

The use of electricity in potentially explosive atmospheres has many features for which the issues concerning the design of electrical equipment and installations raise many difficulties. For low current electrical equipment (interlocking, command, data communications, signaling) the assessment of explosion protection is often carried out by calculation using the technical data available in the specific standard related to protection to explosion requirements.

Currently, the method of calculation uses simplified but covering models. The major advantage of the outcome's certainty on the confirmation of the explosion protection is balanced by the increased rate of rejection. Complex equipment which cannot be assessed by calculation is tested in explosive atmospheres in compliance with the requirements set out in the relevant standard.

In this paper are presented the analysis and characterization of linear sources from within intrinsic safety circuits and issues to be taken into account for the evaluation of these circuits.

**Keywords:** explosive atmosphere; explosion protection; electrical equipment.

---

### 1. Introduction

In industrial installations in which are processed, used or stored flammable or combustible substances is likely to occur an explosive atmosphere, generating an explosion hazard. In this regard, in order to ensure explosion protection, the electrical equipment used in such installations must be correctly chosen to ensure the level of health and safety at the workplace and to prevent their being built into a source of ignition for explosive atmospheres, (Burian S. et al., 2007).

In this paper are presented the analysis and characterization of linear sources from within intrinsic safety circuits and issues to be taken into account for the evaluation of these circuits.

Explosion prevention and explosion protection are of major importance for occupational health and safety in order to minimize losses (both human and material). Explosive atmospheres are defined as a mixture with air, under atmospheric conditions, of flammable substances in the form of flammable gases, mist vapors or combustible dusts, in which, after ignition, combustion is spread throughout the unburned mixture, (Prodan M. et al., 2014).

The mechanism of an explosion generated by a mixture of flammable gas, vapor or mist with air can be expressed by the well-known explosion triangle shown in Figure 1. Thus, the occurrence of an explosion is conditioned by the simultaneous presence of the following three factors:

1. fuel (flammable gases, vapours, dusts /powders, mists);
2. comburent (oxygen, oxidizing substances);
3. efficient ignition source for ensuring the activation of molecules in order to ignite and propagate the fast combustion reaction, (Burian S. et al., 2014).

---

\* Corresponding author. Tel.: +40-727-200-783; fax: +40-254-546-277  
E-mail address: daunt.grecea@insemex.ro.

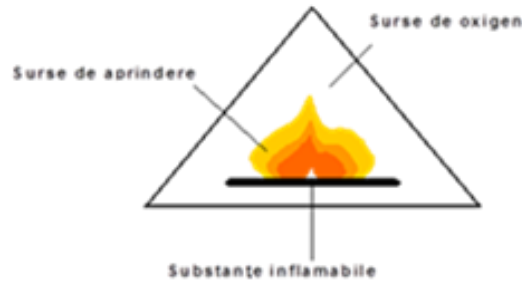


Fig. 1. The explosion triangle

Evaluation and testing of equipment which is part of an explosion protect system in purpose of certification, considers that the risk of explosion has to be minimized in order to ensure security of life and human health, as well as to prevent damage to property and, last but not least, the environment, (Csaszar T. et al., 2012).

All equipment included in a system under construction explosion-protected equipment used in spaces endangered by potentially explosive atmosphere shall meet the following requirements:

- be adequately protected from the explosion;
- to maintain the level of protection for the environmental conditions for which it was built;
- to be able to withstanding all requests (predictable) to which they are subjected during storage, transport, installation and operation of the system. (EN Directive, 2014).

Explosion protection for low current installations can be implemented using the intrinsic safety type of protection.

Intrinsic safety type of protection, based on the separation of the circuit is protected from other circuits and limiting the energy that is protected so that it cannot ignite the explosive atmosphere, (Darie M. et al., 2012).

The explosion protection evaluation for low current equipment involves a process of analyzing the equipment documentation with respect to compliance with the requirements of the relevant explosion protection standards.

The current trend in assessing explosion protection of low current electrical equipment protected by the type of explosion protection intrinsic safety is to increase the share of assessments by calculation applied to equipment using reference tables and charts presented in the relevant standard SR EN 60079- 0; SR EN 60079-11.

Intrinsic safety equipment and parts with intrinsic safety of the associated equipment are classified after recalled above standard as having levels of protection: "ia", "ib" or "ic", (SR EN (IEC) 60079-11, 2012).

## 2. Evaluation of simple circuits with intrinsic safety

Explosion protection implemented by intrinsic safety protection type is based on two main guidelines: limiting the transited and stored energy but also the adoption of separations between intrinsically safe circuits and other circuits.

To evaluate the active intrinsic safety circuits, it is necessary to know first the internal resistance and supply voltage.

For the simplest case, the source can be characterized by two electric constant values, either idle voltage  $U_0$  and internal resistance  $R_i$  or the idle voltage  $U_0$  and short-circuit current  $I_0$  as shown in Figure 2.

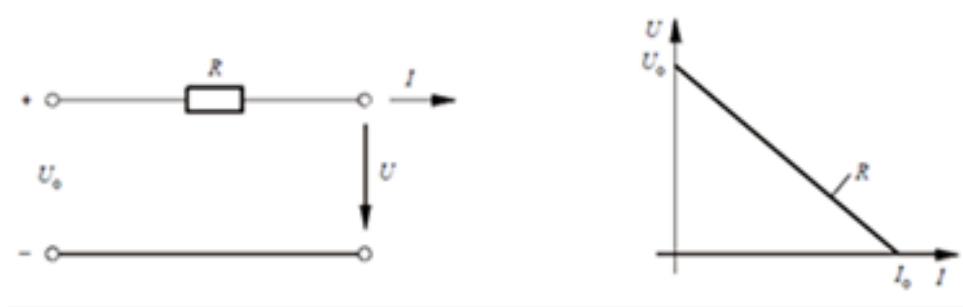


Fig. 2. Resistive circuit with linear characteristic

When the circuit to be evaluated, in terms of capacity, is approximated as a simple circuit, for which there are experimentally curves determined in reference accredited laboratories and recognized at international level, the charts in carts A1 ÷ A6 can be used for evaluation. Specific values of these charts can be processed in tabular form. In both cases, however, the defective conditions and safety coefficients should be considered.

The information given by the following figures relate only to simple circuits and in some cases it can be difficult to apply the information to design practical circuits.

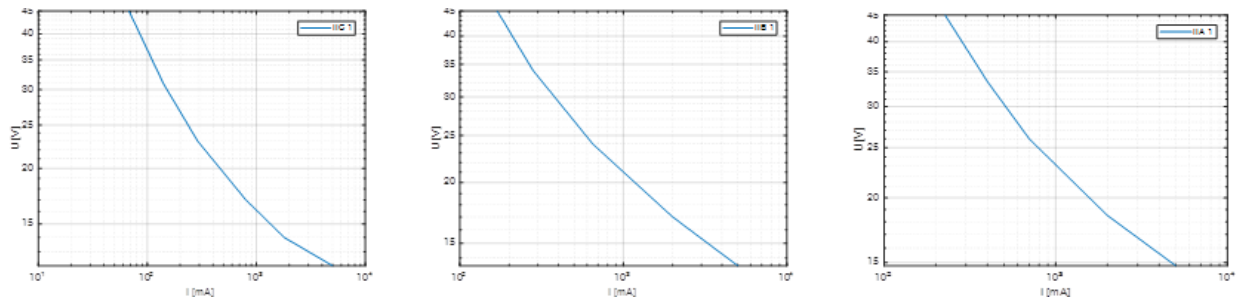


Fig. 3. Curves for evaluation of resistive circuits, group II, safety coefficient 1

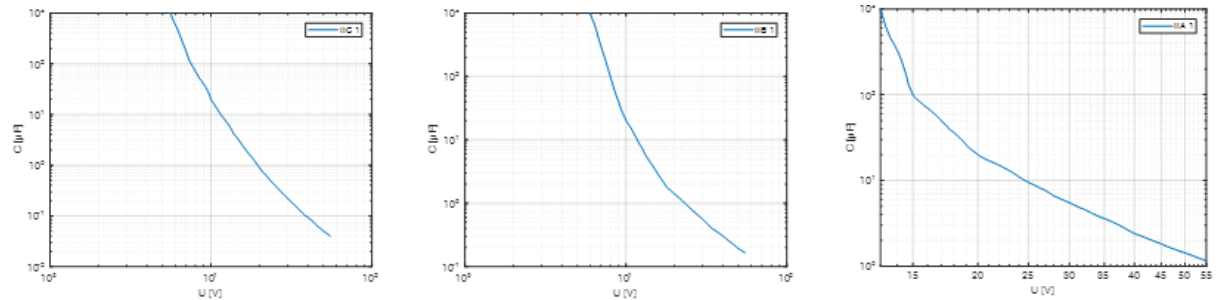


Fig. 4. Curves for evaluation of capacitive circuits, group II, safety coefficient 1

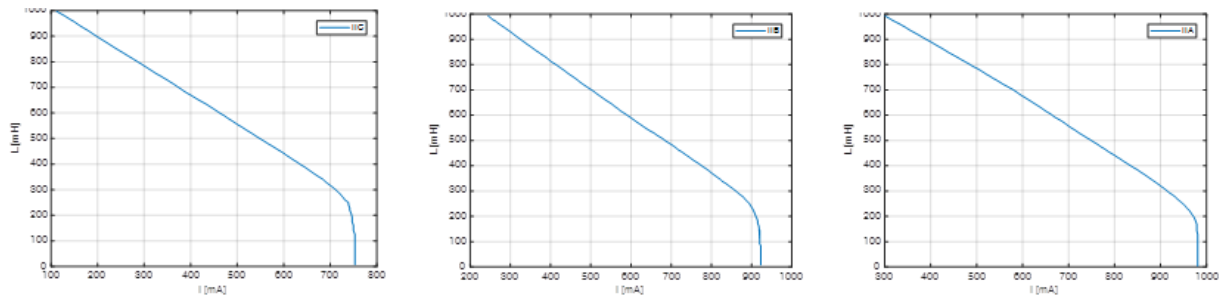


Fig. 5. Curves for evaluation of inductive circuits, group II

A circuit intended for use in potentially explosive environments, with the protection type intrinsic safety "i" must satisfy three basic criteria:

a) does not result in any electrical spark ignition owed when the circuit is rated or tried in accordance with the specified protection level and specified electrical equipment group. This requirement may be satisfied through evaluation, information, current and voltage information on circuit parameters such as inductance and capacity.

b) the temperature class of the equipment with the intrinsic safety is established so as to ensure that the ignition is not caused by hot surfaces. This requirement can be satisfied by estimating the maximum surface temperatures of the components, from the knowledge of their behavior and thermal maximum power to which they may be subjected in operation/fault conditions. The temperature classes of flammable substances (Table 1) are as follows:

Table 1. Temperature classes of flammable substances

Temperature class	Auto-ignition temperature range (AIT) (°C)
T1	$\geq 450$
T2	$300 \leq \text{AIT} \leq 450$
T3	$200 \leq \text{AIT} \leq 300$
T4	$135 \leq \text{AIT} \leq 200$
T5	$100 \leq \text{AIT} \leq 135$
T6	$85 \leq \text{AIT} \leq 100$

c) the circuit should be separated by the other circuits. This can be satisfied by providing isolation distances on the surface and in air insulation distance, electro insulating material, compound or galvanic separation elements.

The following diagram is presented for the evaluation of a circuit intended for use in potentially explosive atmospheres having that type of protection intrinsic safety "i", Figure 6. The steps that you must follow are:

- faling the circuit in one of the levels of protection imposed: "ia", "ib" or "ic";
- identify the values for the  $U_m$  respective  $U_i$ ;
- is determined by the coefficient shall be applied to the security parameters of the electrical circuit rated you as well as for evaluation of surface temperature;
- shall be determined points of application defects in circuit rated depending on the level of protection circuit is employed;
- calculate the maximum values for parameters  $U_i$ ,  $I_i$ , respectively  $P_i$ , taking into account the tolerance values of components depends on the type of protection;
- compare the values obtained with the diagrams of acceptability standard.

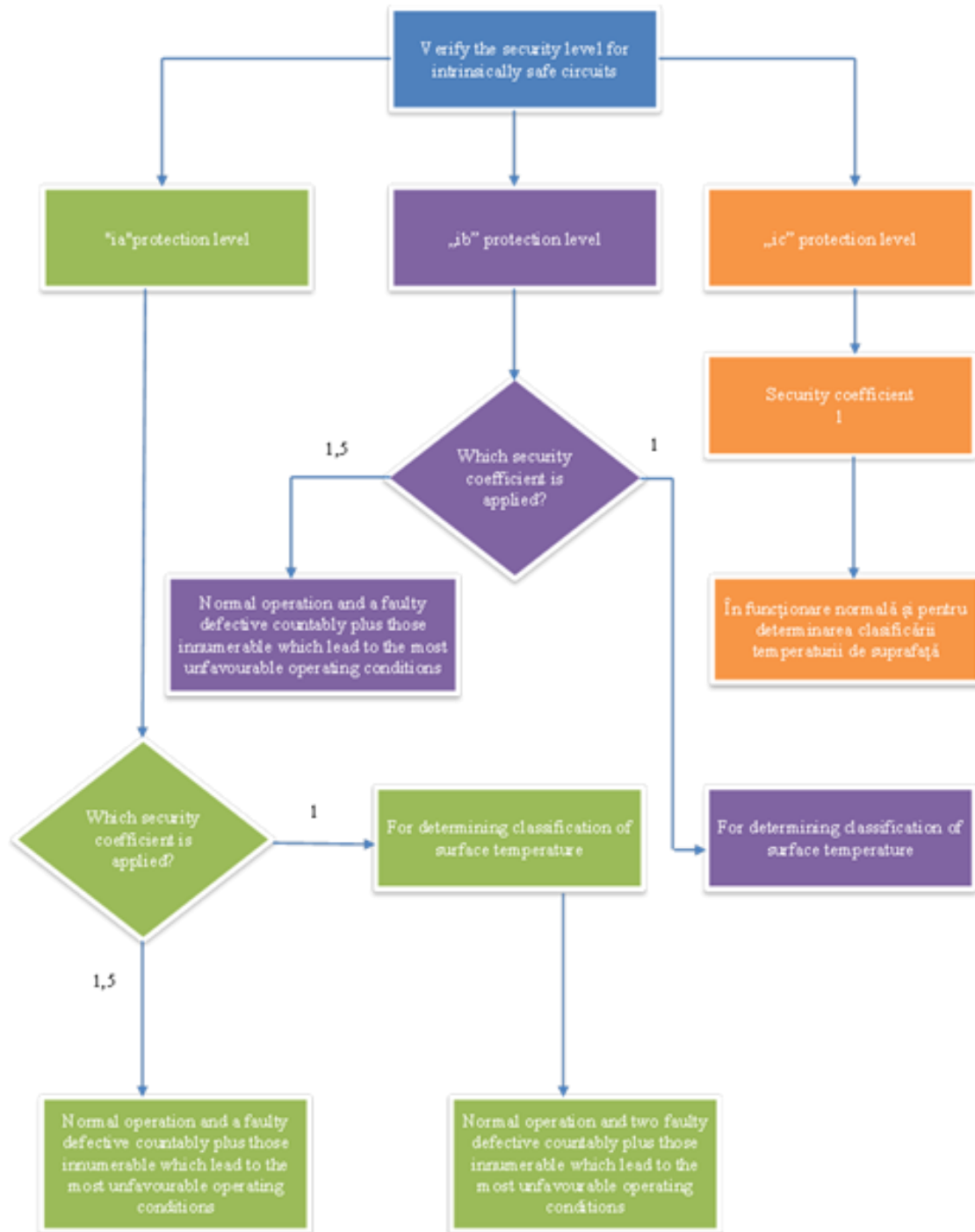


Fig. 6. Diagram of evaluation circuit with intrinsic safety "i"

Based on circuit analysis, a MATLAB computing application was developed to evaluate simple linear circuits using curves and reference tables. Specific values of these diagrams were processed and tabular form. In both cases, however, defective conditions and safety coefficients should be considered.

In Figure 7 is represented the capture of the user interface. This interface allows you to choose the type of simple circuit, the coefficient of safety and gas subgroup required in the evaluation process, based on the charts values, in tabular form inserted and processed in MATLAB in the form of .mat file, graphically indicating validation or invalidation of the protection taking into account the input data (voltage  $U$ , resistance  $R$ , capacitance  $C$ , inductance  $L$ ).

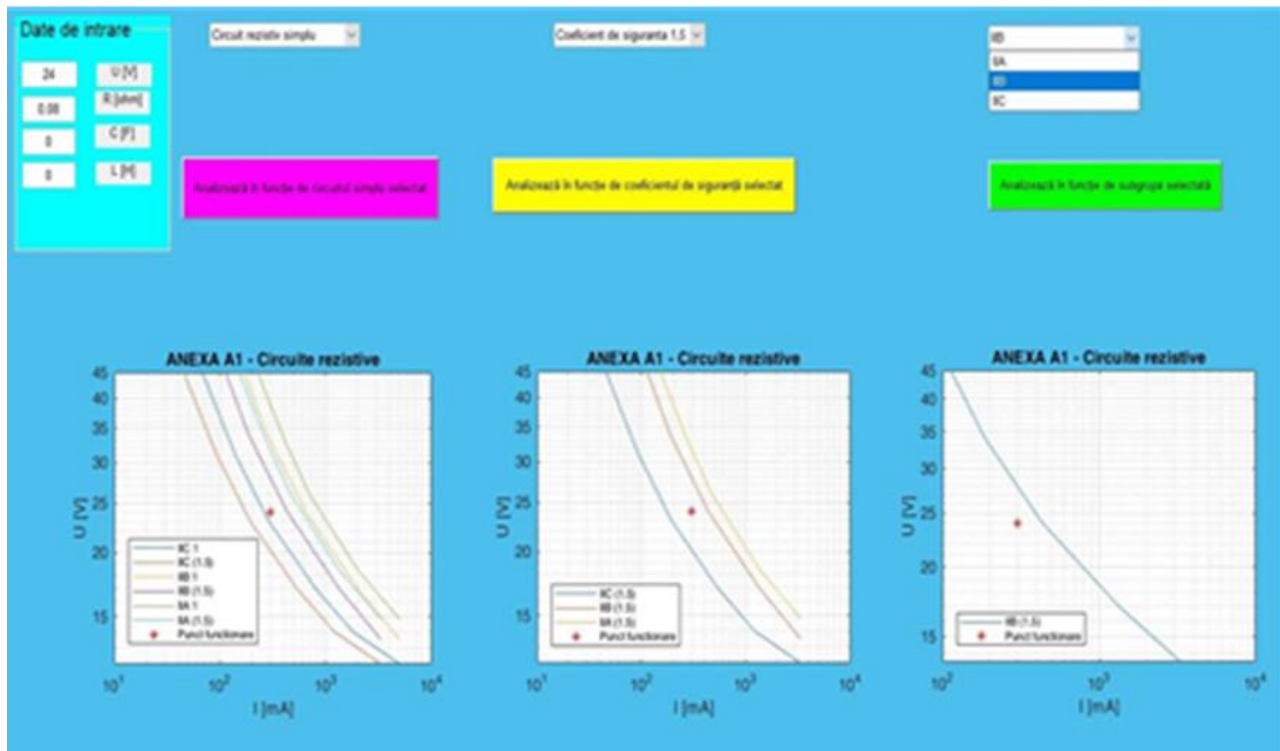


Fig. 7. The user interface of the application

### 3. Conclusion

Joining the IECEx scheme for products certification has imposed the implementation of appropriate methods for assessing the low current circuits in testing laboratory infrastructure. This position involves maintaining a process of updating the procedures for conformity assessment and testing and suitability for carrying out the necessary tests required by the process.

Explosion prevention and explosion protection are of major importance for occupational health and safety in order to minimize losses (both human and material).

This paper aims to increase the ability to evaluate intrinsically safe protection equipment by using the standardized means and the simulation based on the ignition diagrams within the equipment certification body to perform tests on low current equipment protected by the type of protection intrinsic safety intended for use in explosive atmospheres by implementing specific requirements

For simple circuits, especially those with a linear characteristic, it is possible to assess the non-ignition capability using the standardized means and the simulation based on the ignition diagrams.

The increased complexity for the circuits of the equipment involves in the evaluation process, the use of simplified models of circuits that are comprehensive in terms of explosion protection.

### Acknowledgements

This article uses the experimental results obtained within the project PN 18 17 02 01 of the „Nucleu” Program developed with the help of ANCSI.

## References

- Burian S., Ionescu J., Darie M., Csaszar T., Andriş A., *Requirements for Installations in Areas with Explosive Atmosphere, Other than Mines, (in Romanian)*, INSEMEX – Petrosani Publishing House, Romania, (2007).
- Burian S., Ionescu J., Ghicioi E., Darie M., Moldovan L., Csaszar T. Influence of environmental conditions on test mixtures used for testing of equipment with type of protection intrinsic safety, *Proc. Science and technologies in geology, exploration and mining - SGEM 2014*, Albena, Bulgaria, 16-22, June, 2014. 719-726, (2014)
- Csaszar T., Pasculescu D., Darie M., Ionescu J., Burian S., *Method for assessing energy limited supply sources, designed for use in potentially explosive atmospheres*, Environmental Engineering and Management Journal, 11, 1281-1285, (2012).
- Darie M., Ionescu J., Burian S., Csaszar T., Moldovan L., *Ignition probability assessment of low current circuits designed for use in explosive atmospheres*, Environmental Engineering and Management Journal, volume 11/2012, No.5, (2012).
- Prodan M., Ghicioi E., Oancea D., *Correlation of explosion parameters and explosion-type events for preventing environmental pollution*, Environmental Engineering and Management Journal, 13, 1409-1414., (2014).
- EN Directive, *Directive 2014/34/EU of the European Parliament and the Council of 26 February 2014 on the harmonization of the laws of the Member States relating to equipment and protective systems intended for use in potentially explosive atmospheres*, Official Journal of the European Union, No L96/309, 29.03.2014, Brussels, (2014).
- SR EN (IEC) 60079-11:2012. *Explosive atmospheres - Part 11: Equipment protection by intrinsic safety "i"*, ASRO, (2012).



# Considerations regarding the asymmetric pulse and asymmetric power tests of electronic ballasts for fluorescent luminaires with type of protection increased safety “e” designed for use in explosive atmospheres

Lucian Moldovan<sup>a\*</sup>, Sorin Burian<sup>a</sup>, Mihai Magyari<sup>a</sup>,  
Dragoș Fotău<sup>a</sup>, Marcel Rad<sup>a</sup>, Diana Sălășan<sup>a</sup>

<sup>a</sup>INCD-INSEMEX Petroșani, 32-34 Gen. V. Milea Street, Petroșani, Hunedoara County, 332047, Romania

---

## Abstract

The equipment designed for use in explosive atmospheres has to fulfil the requirements of ATEX Directive 2014/34/EU (transposed into Romanian legislation by GD 245/2016).

In order to verify the explosion protection characteristics of equipment these shall be subjected to type tests. In case of fluorescent luminaires with type of protection increased safety “e”, supplied by electronic ballasts, these shall be subjected to the asymmetric pulse and asymmetric power tests.

The purpose of this paper is to present the importance of the asymmetric pulse and asymmetric power tests, and also, to underline the testing methodology developed based on the requirements imposed by the applicable standards.

*Keywords:* type tests; asymmetric pulse; asymmetric power.

---

## 1. Introduction

Assessment of equipment designed for use in potentially explosive atmospheres, represents an important aspect considering the existing explosion risk which has to be minimized in order to ensure people's health and safety, as well as to prevent goods damage and protection of the environment (Moldovan et al., 2012), (Cioca and Moraru, 2012). Assessment of equipment designed to operate in potentially explosive atmospheres is made by verification of the technical documentation and tests (Csaszar T. et al., 2012).

The equipment operating in hazardous explosive atmospheres has to be subjected to conformity assessment procedures, according ATEX Directive 2014/34/EU (transposed in Romanian legislation by Government Decision no. 245/2016) (Directive 2014/34/EU, 2014).

The provisions of the harmonized standards from the SR EN 60079 series are generally used in case of electrical equipment designed for use in potentially explosive atmospheres. The standard SR EN 60079-0 (SR EN 60079-0, 2013) and one or more of the standards containing the specific requirements for the type(s) of protection applied to equipment (ex. SR EN 60079-1 for the type of protection flameproof enclosure “d”, SR EN 60079-7 for the type of protection increased safety “e”, SR EN 60079-11 for the type of protection intrinsic safety “i”) are used for performing the assessment. The evaluation of explosion-proof electrical equipment comprises also type tests (Moldovan et al., 2014).

The type of protection increased safety “e” is based on applying additional measures so as to give increased security against the possibility of excessive temperatures and the occurrence of arcs and sparks in normal service or under specified abnormal conditions (SR EN 60079-7, 2016), (SR EN 60079-14, 2014). Thus, this type of protection can be applied only to electrical equipment that does not produces electrical arcs and sparks in normal operation (i.e. junction boxes, certain types of luminaires, electric motors, heating resistances etc.).

---

\* Corresponding author. Tel.: +40254541621; fax: +40254546277.  
E-mail address: lucian.moldovan@insemex.ro

The standard SR EN 60079-0 indicates the type tests to which all the explosion-proof electrical equipment shall be subjected and the order in which these tests shall be performed (Moldovan et al., 2014).

The specific tests for the type of protection increased safety “e” are specified in the standard SR EN 60079-7 – specific for the type of protection increased safety “e”.

Among the type tests prescribed in this standard, in case of fluorescent luminaires supplied by electronic ballasts, are also included the asymmetric pulse and asymmetric power tests (SR EN 60079-7, 2016).

## **2. Specific conditions for luminaires supplied by electronic ballasts**

Among the equipment operating in potentially explosive atmospheres (chemical plants, refineries, fuel deposits, etc.) luminaires are also included. An important part is represented by luminaires equipped with fluorescent tube lamps using also the type of protection increased safety “e” to provide protection to explosion.

The types of fluorescent tube lamps allowed for use in the type of protection increased safety are as follows:

- for Level of Protection “eb” or “ec”, fluorescent lamps of the cold starting type (CCFL) in accordance with IEC 60081 with single-pin caps (Fa6) in accordance with IEC 60061-1 (SR EN 60079-7, 2016);
- for Level of Protection “eb” or “ec”, tubular fluorescent bi-pin lamps in accordance with IEC 60081 with G5 or G13 lamp caps in accordance with IEC 61195 with pins made of brass. Such lamps shall be connected in a circuit in which they start and run without preheating of the cathodes; only T8, T10, or T12 lamps shall be used. T5 lamps shall be permitted only up to 8 watts (SR EN 60079-7, 2016).
- for Level of Protection “ec”, tubular fluorescent bi-pin lamps in accordance with IEC 60081 with G5 or G13 lamp caps in accordance with IEC 61195 with pins made of brass. Such lamps may be connected in a circuit in which they start and run with preheating of the cathodes; only T5-type HE according IEC 60081 sheet 6520 (14 W), sheet 6530 (21 W), sheet 6640 (28 W), sheet 6650 (35 W), T8, T10, or T12 lamps shall be used (SR EN 60079-7, 2016).

These fluorescent lamp tube luminaires are equipped with electronic ballasts. When using fluorescent lamps equipped with electronic ballasts it is required to provide an additional protection, so as not to allow the supplying of the fluorescent tube by the electronic ballast in case the fluorescent tube reaches the end of life (EOL). This protection has to be provided because at the end of life of the fluorescent tube, the voltage drop at the cathodes level can increase (during the operation of fluorescent lamps, the electron-emitting material on the electrodes is consumed resulting into an increase of energy to release the electrons, that can lead to a higher voltage drop at the electrodes of the fluorescent lamps) and result in a temperature increase in the cathodes area (Stahl, 2018).

Because the electronic ballast functions as a constant current source, a higher voltage drop will lead to a power consumption increase. The increase of temperature can exceed the maximum surface temperature of the luminaire (for the type of protection increased safety the maximum surface temperature is determined considering both the temperature measured on external surfaces and the temperature measured on the internal surfaces of the equipment).

Thus, the maximum dissipated power at the cathodes level shall not exceed certain levels over which the operational safety cannot be guaranteed (when operating in a potentially explosive atmosphere).

In order to achieve explosion protection for a luminaire equipped with fluorescent lamps supplied by electronic ballasts there are certain specific condition that have to be fulfilled, as provided in the specific standard SR EN 60079-7.

In case of luminaires equipped with tubular fluorescent bi-pin lamps employing electronic ballasts, the maximum ambient temperature shall not exceed 60 °C. Also the temperature classes T5 and T6 are not be permitted (SR EN 60079-7, 2016).

### *2.1. Power dissipation of cathodes of lamps supplied by electronic ballasts*

#### *2.1.1. Luminaires in Level of Protection “eb”*

The asymmetric pulse test and the asymmetric power dissipation test shall be conducted (according SR EN 60079-7). The maximum cathode power observed during the test shall not exceed the values given in Table 1. The tests shall be conducted at the minimum and maximum ambient temperature of the luminaire (SR EN 60079-7, 2016).

#### *2.1.2. Luminaires in Level of Protection “ec”*

The asymmetric pulse test and the asymmetric power dissipation test shall be conducted (in accordance with IEC 61347-2-3). The maximum cathode power observed during the test shall not exceed the values given in Table 1. The tests shall be conducted at the minimum and maximum ambient temperature of the luminaire (SR EN 60079-7, 2016).

Table 1 – Power dissipation of cathodes of lamps supplied by electronic ballasts

Fluorescent tube type	Level of protection		Ambient temperature for the luminaire °C	Temperature class allowed	maximum cathode power W
	eb	ec			
T8 /T10/T12	Permitted	Permitted	$\leq 40$	T4	10
T8 /T10/T12	Permitted	Permitted	$\leq 60$	T4	8
T8 /T10/T12	Permitted	Permitted	$\leq 60$	T3	10
T5 (8 W)	Permitted	Permitted	$\leq 40$	T4	4
T5 (8 W)	Permitted	Permitted	$\leq 60$	T3	4
T5-HE (8 W to 35 W)	Excluded	Permitted	$\leq 60$	T4	5

In case of testing the fluorescent tube luminaires to verify the end of life conditions any of the tests (asymmetric pulse test, asymmetric power test and open filament test) can be used according IEC 61347-2-3 (IEC 61347-2-3, 2018).

## 2.2. The asymmetric pulse test

The ballast shall have adequate protection to prevent lamp cap overheating at the end of the lamp life. The electronic diagram needed to perform the test is presented in Figure 1 (SR EN 60079-7, 2016). When subjected to the asymmetric pulse test, the maximum cathode power shall not exceed the values given in Table 1 (SR EN 60079-7, 2016).

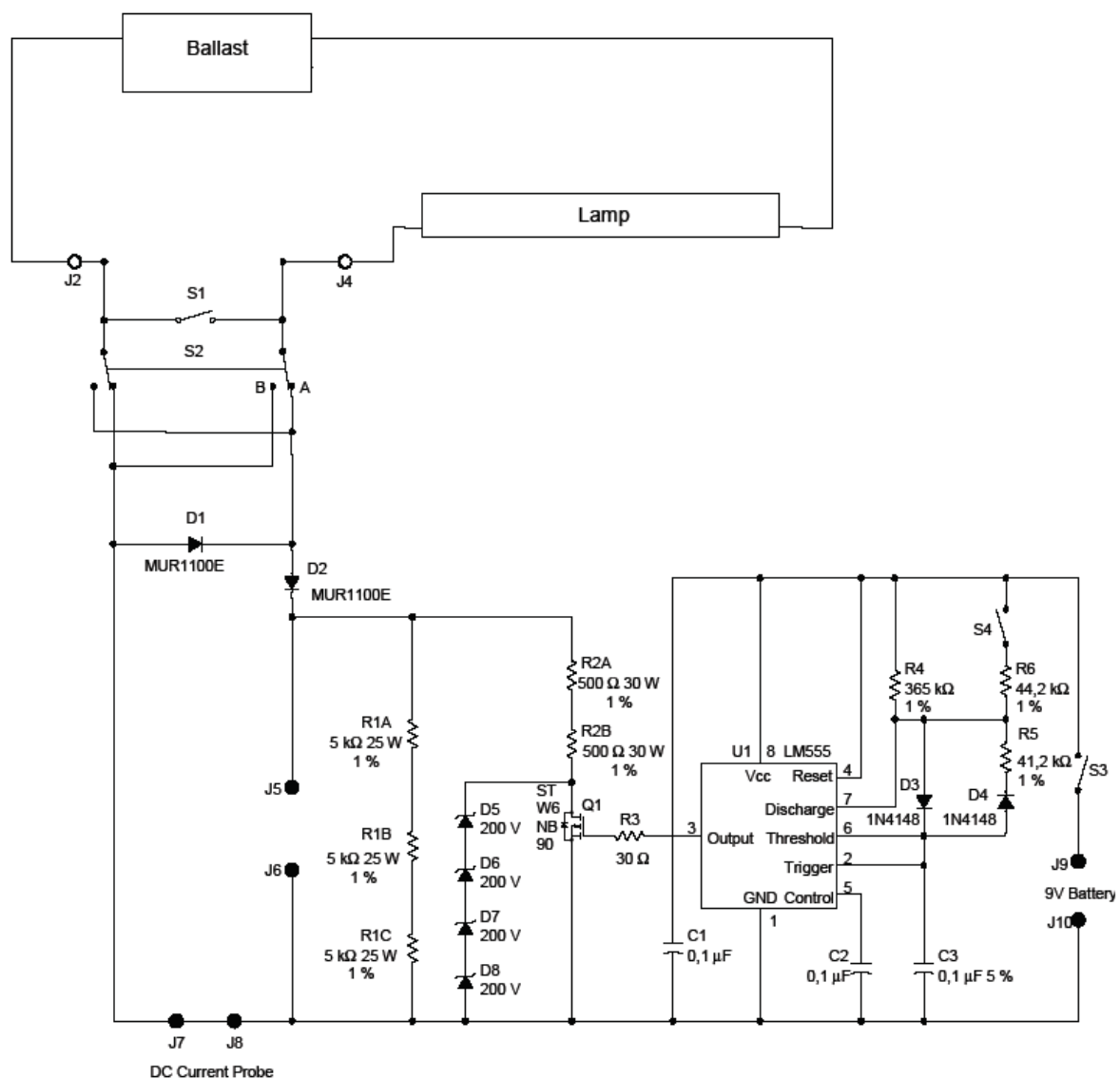


Fig. 1 Asymmetric pulse test circuit (SR EN 60079-7, 2016)

Generally speaking, the testing procedure consists in measuring the sum of the average power dissipated in the power resistors, R1A to R1C and R2A, R2B and the Zener diodes, D5 to D8. This power should be measured as the average value of the product of the voltage between terminals J5 and J6 times the current flowing from J8 to J7. The voltage should be measured with a differential voltage probe, and the current should be measured with a d.c. current probe. A digital oscilloscope can be used for the multiplication and averaging functions. If the ballast operates in a cycling mode, the averaging interval should be set to cover an integer number of cycles (each cycle is typically greater than 1 s). The sampling rate and number of samples included in the calculations should be sufficient to avoid aliasing errors (SR EN 60079-7, 2016).

In case the measured power is greater than the values given in Table 1, the ballast has failed and the test is discontinued (SR EN 60079-7, 2016).

If the protection circuit in the ballast has switched off the lamp, then the ballast shall be restarted (close S1).

The average power dissipated in the resistors shall be measured for both positions “A” and “B”. The ballast shall pass both position 'A' and position 'B' tests (SR EN 60079-7, 2016).

For multi-lamp ballasts, the tests shall be made for each lamp position. A multi-lamp ballast shall pass the tests for each lamp position (SR EN 60079-7, 2016).

For ballasts that operate multiple lamp types, each lamp type specified shall be tested (SR EN 60079-7, 2016).

The mounting for testing of fluorescent lamps used in level of protection “ec” is similar to the one in Figure 1. This includes also the possibility of testing fluorescent lamps with preheating of the cathodes (using a specific circuit and a transformer between J2 and J4).

### *2.3. Asymmetric power test*

The ballast shall have adequate protection to prevent lamp cap overheating at the end of the lamp life. When subjected to the asymmetric power test, the maximum cathode power shall not exceed the values given in Table 1 with the lamp at a temperature representative of its maximum service temperature (SR EN 60079-7, 2016).

The testing procedure considers the electronic diagram in Figure 2. The inductance of resistor R1 has to be as low as possible (ohmic resistor) due to the high frequency of this circuit (SR EN 60079-7, 2016).

The electronic ballast shall be tested so as to demonstrate that it will be able to turn off the lamp when the power required by the cathodes circuit is higher than the values in Table 1 (SR EN 60079-7, 2016).

First, the resistance of R1 will be increased rapidly (within 15 s), until the power dissipated by resistor R1 equals the test wattage value of 20 W (or 8 W for the T5 lamp 8 W). If the ballast switches off before reaching the test wattage, or after reaching the test wattage, the ballast shall be retested to demonstrate that the maximum possible continuous power, without switching off, is less than or equal to the values given in Table 1 (SR EN 60079-7, 2016).

Then, the resistance of R1 will be increased rapidly (within 15 s) until the power dissipated by resistor R1 equals approximately 5 W (or 2 W for the T5 lamp 8 W). If the ballast fails to turn off in 2 min, the test is stopped and repeated with an increased resistance in R1 until approaching a target power dissipation of the values given in Table 1 (three or four steps is sufficient) (SR EN 60079-7, 2016).

If the ballast fails to switch off within 2 min at a power less than or equal to the values given in Table 1, the ballast has failed and the test is discontinued. If the ballast does not switch off in the previous test, but limits the power in R1 to a value less than the test wattage of 20 W (or 8 W for the T5 lamp 8 W), the value of R1 is set to the value which produces the maximum wattage (SR EN 60079-7, 2016).

If the 20 W (or 8 W for the T5 lamp 8 W) value was reached (when testing from 5W (or 2 W for the T5 lamp 8 W) to the values prescribed in Table 1), an additional period of 15 s will be considered. If the 20 W (8 W for the T5 lamp 8 W) value was not reached in that test and the limitation obtained (to a maximum value of 20 W (or 8 W for the T5 lamp 8 W)) is applicable, an additional period of 30 s will be considered. The measured power in resistor R1 should be reduced to the values given in Table 1 or less, otherwise the ballast has failed and the test is discontinued (SR EN 60079-7, 2016).

The ballast shall pass the test in both positions “A” and “B” (SR EN 60079-7, 2016).

For multi-lamp ballasts, the test procedure is repeated for each lamp position. A multi-lamp ballast shall pass the tests for each lamp position (SR EN 60079-7, 2016).

For ballasts that operate multiple lamp types each lamp type specified shall be tested (SR EN 60079-7, 2016).

In any of the configurations, if the power in resistor R1 is greater than the values given in Table 1, the ballast has failed and the test is discontinued (SR EN 60079-7, 2016).

To perform the test in case of fluorescent tube luminaires in level of protection “ec” the test scheme from the standard IEC 61347-2-3 shall be used (which allows also the testing of fluorescent lamps with preheating of the cathodes).

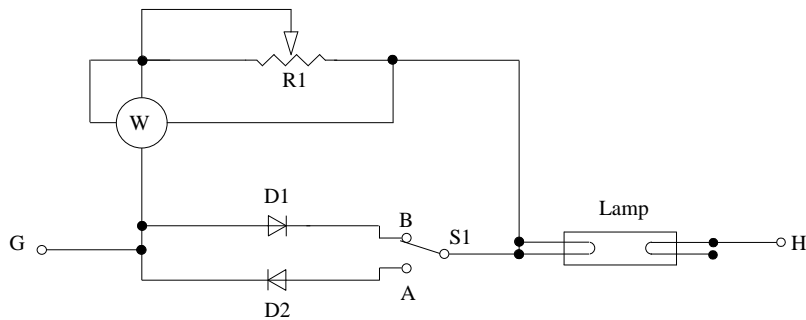


Fig. 2 Asymmetric power detection circuit (SR EN 60079-7, 2016)

### 3. Conclusions

In this paper were presented aspects regarding the end of life of fluorescent tubes, the requirements that shall be fulfilled by electronic ballasts related to the type of protection increased safety “e”, the specific tests that are to be applied in this case (asymmetric pulse test and asymmetric power test) and the testing methodology as required by standards.

The electronic ballasts used to supply luminaires equipped with fluorescent tubes shall ensure adequate protection against overheating of lamp cap(s) at the end of life of the fluorescent tube (EOL).

The asymmetric pulse test and the asymmetric power test are two important tests that shall be applied in case of fluorescent tube luminaires equipped with electronic ballasts in order to verify the adequate protection against end of life (EOL).

Even if IEC 61347-2-3 provides multiple methods to test the EOL protection ensured by the electronic ballast (testing by one single method if considered enough), in case of luminaires with type of protection increased safety (because they are intended for use in potentially explosive atmospheres) both tests shall be passed (asymmetric pulse test and asymmetric power test) in order to qualify an electronic ballast.

### Acknowledgements

This paper was developed within a Research Program - Nucleu Program 2018, project PN 18 17 02 01 - Researches for developing the assessment and testing of technical equipment designed for use in areas with hazard of explosion and of personal protective equipment.

### References

- Cioca, L.I., Moraru R.I., *Explosion and/or Fire Risk Assessment Methodology: A Common Structured for Underground Coalmine Environments*, Archives of Mining Sciences, 57, 53-60, (2012).
- Csaszar, T., Pasculescu D., Darie M.; Ionescu J., Burian S., *Method for assessing energy limited supply sources, designed for use in potentially explosive atmospheres*, Environmental Engineering and Management Journal, 11, 1281-1285, (2012).
- Friedmann, M., Moldovan L., *Implementation of test methods for assessment of electrical apparatus with the type of protection increased safety "e"*, Mining Revue, 16, 18-20, (2010).
- Moldovan, L., Burian S., Friedmann M., Magyari M., Fotău D., Colda C., *Considerations regarding the torque test for bushings and thermal shock test, applicable to electrical equipment designed for use in explosive atmospheres*, Proc. 6th Int. Mult. Scient. Symp. UNIVERSITARIA SIMPRO, Petroșani, University of Petroșani, Romania, 311-314, (2014).
- Stahl, R., *Exlux 6000 - tried & proven technology has just been made better*, [http://www.electromach.com/uploads/media/EVG6042-exlux\\_01.pdf](http://www.electromach.com/uploads/media/EVG6042-exlux_01.pdf), (2018).
- Directive 2014/34/EU of the European Parliament and of the Council of 26 February 2014 on the harmonisation of the laws of the Member States relating to equipment and protective systems intended for use in potentially explosive atmospheres (recast), Official Journal of the European Union, No L96/309, 29.03.2014, Brussels (2014).
- IEC 61347-2-3, *Lamp controlgear – Part 2-3: Particular requirements for a.c. supplied electronic ballasts for fluorescent lamps*, (2011).
- SR EN 60079-0, *Explosive atmospheres - Part 0: Equipment – General requirements*, ASRO, (2013).

SR EN 60079-7, *Explosive atmospheres. Part 7: Equipment protection by increased safety "e"*, ASRO, (2016).

SR EN 60079-14, *Explosive atmospheres – Part 14: Electrical installations design, selection and erection*, ASRO, (2014).

## Study and evaluation of requirements for breathing and draining devices

Marcel Daniel Rad<sup>a\*</sup>, Sorin Burian<sup>a</sup>, Mihai Magyari<sup>a</sup>, Lucian Moldovan<sup>a</sup>, Dragos Fotău<sup>a</sup>,  
Diana Sălășan<sup>a</sup>

<sup>a</sup>National Institute for Research and Development in Mine Safety and Protection to Explosion – INSEMEX PETROSANI -Romania

---

### Abstract

The evaluation of explosion-proof electrical equipment for certification is particularly important given the risk of explosion and must be minimized. This in order to ensure the safety of life, health of workers, to prevent damage to goods and the environment when they meet the essential security requirements at European level.

Directive 2014/34 / EU states that equipment used in explosive atmospheres must be designed to operate without endangering the environment for which it is intended.

This paper proposes the study and evaluation of the requirements for the breathing and drainage devices. In order to verify explosion protection, the representative samples made available by explosion-protected equipment manufacturers are tested under the worst possible conditions that may occur in practice.

**Keyword:** Flameproof enclosure; explosion protection; breathing and draining devices; explosive atmosphere; permeable metallic materials.

---

### 1. Introduction

The paper deals with the study of the requirements for the testing of drainage and breathing devices used in electrical equipment with flameproof enclosures type of protection. Several studies have been conducted on the reliability of electrical equipment and installations.

Types of protection are all the specific measures applied to electrical equipment to avoid the ignition of an ambient explosive atmosphere.

According to Directive 2014/34 / EU, users of technological installations in areas with explosive atmospheres have to follow successively three stages. Preventing the formation of explosive atmospheres, avoiding the ignition of explosive atmospheres, limiting the harmful effects of an explosion to ensure the health and safety of workers (Directive 2014/34/EU, 2014).

### 2. Additional requirements for drainage and breathing devices.

#### 2.1 General

Drainage and breathing devices are generally used for electric motors with a flameproof enclosure protection. For the design and construction of motors with a type of flameproof enclosure protection, it is necessary for the beneficiary to formulate precisely and in detail the requirements regarding the operation of the motors in accordance with the ATEX directive. (Directive 2014/34/EU, 2014)

Being designed to operate installations in explosive atmospheres (chemical industry, petroleum industry, mining industry, etc.), these engines are often built into the flameproof enclosure protection module, its outer part (case, shields, terminal box, clamping elements) having to withstand an internal explosion of an explosive mixture that penetrated the interior without suffering deformations and without transmitting the flame from the inside out to an explosive atmosphere surrounding the casing. (Directive 2014/34/EU, 2014)

---

\* Corresponding author. Tel.: +40733546114;  
E-mail address: marcel.rad@insemex.ro



For this, it is necessary to have maximum admissible interstices at joints or other passageways, depending on explosion categories and subcategories (ATEX). (Directive 1999/92/Ec) The engines are distinguished by a robust mechanical construction, made in a wide range of constructive shapes normalized by the major manufacturers of electric machines. The external shape of the casing depends on the type of motor protection as well as on the cooling mode. In the case of a closed machine equipped with an axial cooling system, the casing is constructed with ribs to increase the cooling surface. In the case of an internal cooling machine, the casing is smooth outside. (Rad, 2018)

Standard SR EN 60079-1 shows all types of possible joints encountered when making flameproof enclosures as well as joint parameter values. The standard also mentions the materials used for the carcasses.

### **3 Breathing and draining devices which form part of a flameproof enclosure**

#### *3.1 General*

Breathing and draining devices shall incorporate permeable elements which can withstand the pressure created by an internal explosion in the enclosure to which they are fitted, and which shall prevent the transmission of the explosion to the explosive atmosphere surrounding the enclosure. (SR EN 60079-1, 2015)

They shall also withstand the dynamic effects of explosions within the flameproof enclosure without permanent distortion or damage which would impair their flame-arresting properties. They are not intended to withstand continuous burning on their surfaces. (Rad, 2018)

These requirements apply equally to devices for the transmission of sound but do not cover devices for relief of pressure in the event of internal explosion, use with pressure lines containing gas which is capable of forming an explosive mixture with air and is at a pressure in excess of 1,1 times atmospheric pressure. (SR EN 60079-0, 2013)

#### *3.2 Openings for breathing or draining*

The openings for breathing or draining shall not be produced by deliberate enlargement of gaps of flanged joints.

The composition limits of the materials used in the device shall be specified either directly or by reference to an existing applicable specification.

The elements of breathing or draining devices for use in an explosive gas atmosphere containing acetylene shall comprise not more than 60 % of copper by mass to limit acetylide formation.

The dimensions of the breathing and draining devices and their component parts shall be specified. (SR EN 60079-0, 2013)

### **4 Type tests for breathing and draining devices used as Ex components**

#### *4.1 General*

Attachment of the sample device under test shall be made on the end of the test rig enclosure in the same manner as it would normally be mounted on a flameproof enclosure. The test shall be performed on the sample after the impact test. (SR EN 60079-1, 2015)

The impact test may be performed on the sample, separate from the test enclosure, when it is mounted on a plate that forms the end part of the test rig enclosure.

For devices with non-measurable paths, the maximum bubble test pore size of the sample shall be not less than 85 % of the specified maximum bubble test pore size. (SR EN 60079-0, 2013)

#### *4.2 Bubble test*

For buloscopic verification of sintered materials, materials used for making drainage and breathing devices, is shown in Fig. 1.

The buloscopic hair size corresponds to the minimum differential pressure at which the first bubbles appear continuously. For this reason, this pressure is sometimes called the minimum bubble pressure or the first bubble. The appropriate capillary diameter is called maximum pore diameter or maximum pore size.

When the pressure exceeds the minimum burst pressure (the first bubble point), more bubbles appear on the sample. For a given aspect, the corresponding pressure can lead to the definition of a conventional pore size. (SR EN 24003 - 1996)

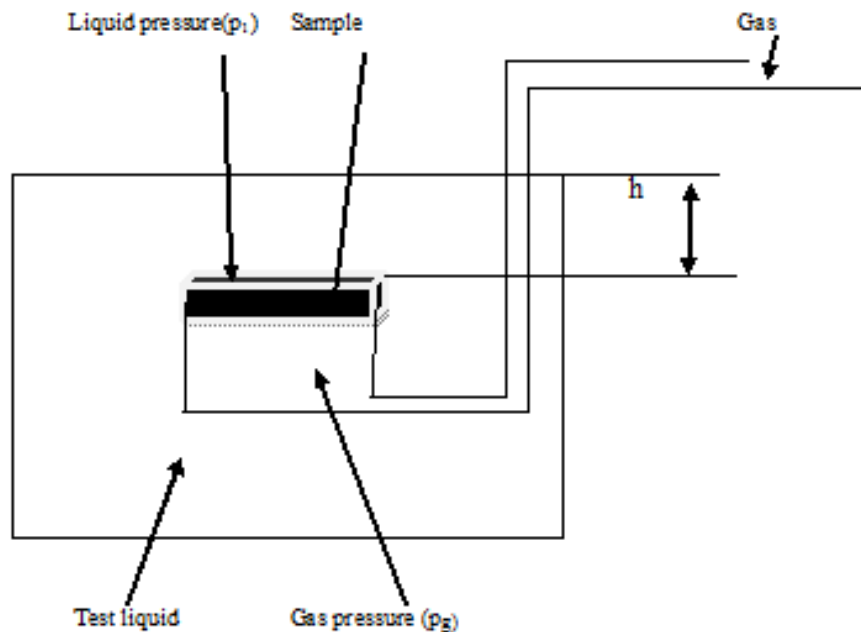


Fig. 1. Block diagram for bulboscopic determination

### 4.3 Thermal tests

#### 4.3.1 General

After the bubble test, breathing and draining devices as Ex components shall be subjected to the thermal tests based on the maximum intended flameproof enclosure volume, but no less than the volume of the test rig in Figure 2. (SR EN 60079-1, 2015)

Breathing and draining devices intended for multiple use in any single flameproof enclosure shall be tested additionally with the enclosure.

#### 4.3.2 Test procedure

For enclosure volumes of less than or equal to 2,5 l, the test rig assembly with all four sections, as shown in Figure 2, shall be used, and the test procedure shall be carried out as follows:

- the position of the ignition source shall be at the enclosure inlet and 50 mm from the inside of the end-plate housing the device and the results observed;
- the test mixtures shall;
- the temperature of the external surface of the device shall be monitored during tests;
- any device shall be operated as specified by the manufacturer's documentation. After each of five tests, the explosive mixture shall be maintained external to the device for a sufficient time to allow any continuous burning on the face of the device to become evident, for at least 10 min, so as to increase the temperature of the external surface of the device or to make temperature transfer to the outer face possible; and
- the tests shall be carried out five times for each gas mixture for the gas groups in which the device is intended for use.

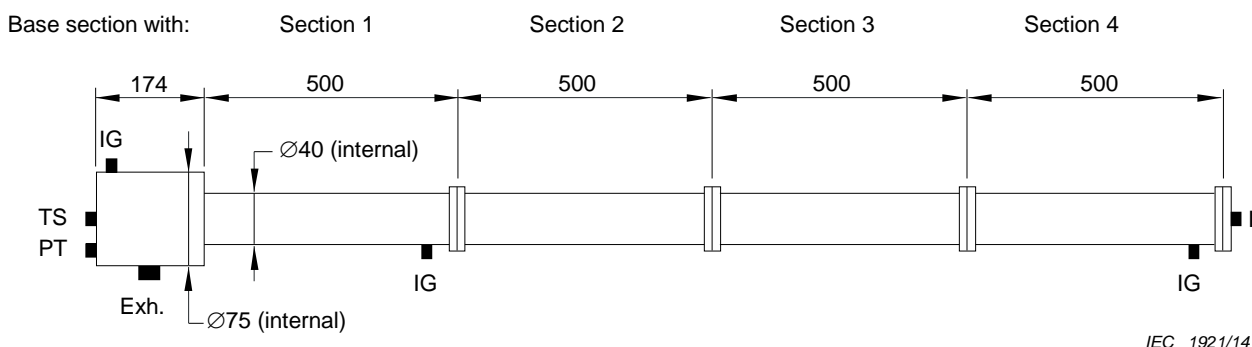


Fig 2. Component test rig for breathing and draining devices

For enclosure volumes of greater than 2,5 l, a representative enclosure of the intended volume shall be used, and the test procedure shall be carried out as follows:  
the test mixtures shall, as appropriate;  
the temperature of the external surface of the device shall be monitored during tests;  
any device shall be operated as specified by the manufacturer's documentation.

After each of five tests, the explosive mixture shall be maintained external to the device for a sufficient time to allow any continuous burning on the face of the device to become evident, for at least 10 min, so as to increase the temperature of the external surface of the device or to make temperature transfer to the outer face possible; and the tests shall be carried out five times for each gas mixture for the gas groups in which the device is intended for use. (SR EN 60079-1, 2015)

#### *4.3.3 Acceptance criteria*

During the thermal tests, no flame transmission shall occur and no continuous burning shall be observed. The device shall show no evidence of thermal or mechanical damage or deformation which could affect its flame-arresting properties.

The measured external surface temperature rise of the device shall be multiplied by a safety factor of 1,2 and added to the maximum service temperature of the device for the determination of the temperature class of the electrical equipment.

### *4.4 Test for non-transmission of an internal ignition*

#### *4.4.1 General*

After the bubble test, this test shall be carried out on a standard test rig, as illustrated in Figure 2, with the following additions and modifications.

#### *4.4.2 Test procedure*

- The position of the ignition source shall be as shown in Figure 2:
    - a) at the inlet end; and
    - b) at 50 mm from the inside of the end-plate housing the device.
  - For the purposes of the test, the test rig shall be assembled for each gas group, in accordance with Figure 2, and have the following number of sections:
    - Group I and Group IIA: one section of test rig assembly;
    - Group IIB and Group IIC: four sections of test rig assembly.
  - The gas mixture within the test rig enclosure shall be ignited and the tests shall be made five times at each ignition point.
  - For breathing and draining devices of Groups I, IIA and IIB having either measurable paths or non-measurable paths.
  - For breathing and draining devices of Group IIC with measurable paths,.
- For breathing or draining devices of Group IIC with non-measurable paths.

#### *4.4.3 Acceptance criteria*

During the test, no ignition shall be transmitted to the surrounding test chamber.

### *4.5. Test of the ability of the breathing and draining device to withstand pressure*

#### *4.5.1 Test procedure*

The reference test pressures in each gas group are:

Group I	1 200 kPa,
Group IIA	1 350 kPa,
Group IIB	2 500 kPa,
Group IIC	4 000 kPa.

For the purpose of the test, a thin flexible membrane is fitted over the inner surfaces of the breathing and draining devices. The reference pressure shall be one of the relevant pressures given above for the gas group for which the component is intended. (SR EN 60079-1, 2015) One of the following overpressure tests shall be applied:

- 1,5 times the reference pressure for a period of at least 10 s. Then each component shall be submitted to a routine test; or
- 4 times the reference pressure for a period of at least 10 s. If this test is successful, the manufacturer is not required to apply the routine test to all future components of the tested type.

#### 4.5.2 Acceptance criteria

After the overpressure tests, the device shall show no permanent deformation or damage affecting the type of protection.

#### 4.6. Ex component certificate

The Ex component certificate shall include, in the schedule of limitations, the details necessary to properly select a breathing or draining device for attachment to a type tested flameproof enclosure. The schedule of limitations shall include, as a minimum, the following:

- a. the maximum recorded surface temperature obtained during the type test corrected to 40 °C, or to the higher marked ambient;
- b. service temperature range for non-metallic enclosures and non-metallic parts of enclosures;
- c. the maximum permitted enclosure volume (based on the thermal test) if greater than 2,5 l;
- d. a requirement that each Ex component or package of Ex components be accompanied by a copy of the certificate, together with the manufacturer's declaration stating compliance with the certificate conditions, and confirmation of the material, maximum bubble test pore size and minimum density, where applicable; and special mounting instructions, if any.

### 5. Conclusions

As a result of the work titled: "Study and evaluation of the requirements regarding the breathing and drainage devices ", the following conclusions were drawn:

- the requirements of standard SR EN 60079-0 for electrical equipment used in explosive environments have been analyzed;
- the requirements of standard SR EN 60079-1 for drainage and breathing devices;
- the requirements of standard SR EN 60079-1 have been analyzed regarding the necessary tests to be performed on drainage and breathing devices;
- the test requirements for the drainage and blowing devices in bulk, correlated with the other specific tests to which the equipment is to be subjected, have been presented in the paper, establishing the order of the tests in accordance with the specific standard;
- the components required to achieve the test bench for the pressure and non-explosion test for the drainage and blowing devices have been established;
- the required components for the test stand were prepared for the buloscopic test of drainage and breathing devices;
- the block diagram of stalls for pressure, explosion-proof and buloscopic test stands that meet the test requirements specified in the standard.

### Acknowledgements

This work is part of the Core Program: "Researches for the development of evaluation capacity, testing of technical equipment for use in explosion risk areas and protective equipment" - PN 18 17 02 01

### References

- Rad Marcel, *Increased reliability of electrical equipment used in explosive environments*, Doctoral Thesis, March, (2018).
- Romanian Standard, SR EN 60079-1 *Explosive atmospheres - Part 1: Equipment protection by flameproof enclosures "d"*, Romanian Association for Standardization – ASRO, Bucharest, Romania, (2015).
- Romanian Standard, SR EN 60079-0 *Explosive atmospheres - Part 0: Equipment – General requirements*, Romanian Association for Standardization – ASRO, Bucharest, Romania, (2013).

Directive 2014/34/EU *Of the European Parliament and of the Council of 26 February 2014 on the harmonization of the laws of the Member States relating to equipment and protective systems intended for use in potentially explosive atmospheres* (recast) Text with EEA relevance, (2014).

Directive 1999/92/Ec *Of The European Parliament And Of The Council of 16 December 1999 on minimum requirements for improving the safety and health protection of workers potentially at risk from explosive atmospheres* (15<sup>th</sup> individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC), (1999).

Standard SR EN 24003 -1996 - *Permeable sintered metallic materials. Determination of pore size*, (1996).

## Thermal endurance tests performed on equipment used in potentially explosive areas

Dragoș Fotău<sup>a\*</sup>, Sorin Burian<sup>a</sup>, Mihai Magyari<sup>a</sup>, Lucian Moldovan<sup>a</sup>, Marcel Rad<sup>a</sup>,  
Diana Sălașan<sup>a</sup>

*<sup>a</sup>National Institute for Research and Development in Mine Safety and Protection to Explosion – INSEMEX Petroșani, 32-34 G-ral Vasile Milea Street, Petroșani 332047, Romania*

---

### Abstract

Evaluation of explosion-proof protected electrical equipment in scope of certification is extremely important considering the risk of explosion that has to be minimized in order to ensure life safety and health of workers and to prevent damaging of property and the environment, as well as free movement of goods when they meet the essential safety requirements at European level.

The purpose of this paper is to present aspects regarding the importance of thermal endurance tests performed on the electrical equipment used in potentially explosive atmosphere.

The paper also presents laboratory facilities for performing the thermal endurance test.

**Keywords:** thermal test; flameproof enclosure; increased safety; certification; explosive atmosphere.

---

### 1. Introduction

Using electric energy in potentially explosive atmospheres brings forward several particularities therefore the problems that appear during the design, construction and operation of electrical devices and installations brings forward numerous difficulties, their approach requiring special attention considering all the technical, economical and labor safety aspects. (Fotău et al., 2017).

The risk of explosion may appear in all the fields of activity in which flammable substances are involved, such as gases, vapors, dusts, mists, which mixed with air may result in potentially explosive atmospheres. (Ghicioi et al., 2017)

In order to increase the occupational health and safety level in potentially explosive atmospheres generated by flammable gases or explosive dusts we have to prevent the ignition of explosive atmospheres. In order to do this the electrical equipment used in such areas must be made with different types of protection so that it cannot ignite the explosive mixture surrounding it. (Fotău et al., 2016).

The type of protection means the specific measures applied to electrical equipment (Pasculescu et al., 2012), to avoid ignition of a surrounding explosive atmosphere. (Standard IEC 60079-0., 2013).

For each type of protection applied to electrical equipment used in potentially explosive atmosphere, a wide range of type tests have been developed so that they can be used safely. (Standard IEC 60079-0., 2013).

In addition to type tests, on the equipment the thermal endurance test must be performed.

### 2. Thermal endurance tests performed on equipment used in potentially explosive atmosphere

The enclosure of the equipment, due to unfriendly conditions in which they operate, can be damaged quite easily. In order to preserve the type of protection of the equipment it is very important that their enclosures remain intact in the event of an accidental impact.

---

\* Corresponding author. Tel.: +4-073-139-0816; fax: +40-254-546-277.  
E-mail address: dragos.fotau@insemex.ro.

During the certification process, the equipment is subjected to an impact test to determine the resistance of the enclosure. According to the standardized requirements before carrying out these tests, the equipment enclosure must be subjected to thermal endurance tests. This test is performed using the climate chamber, specifically designed for testing enclosures. (Standard IEC 60079-0., 2013).

### 2.1. Thermal endurance to heat

The thermal endurance to heat shall be determined by submitting the enclosures or parts of enclosures in non-metallic materials, on which the integrity of the type of protection depends, to tests according to Table 1. (Standard IEC 60079-0., 2013), (Standard IEC 60079-1., 2015).

Table 1 – Thermal endurance test

Service temperature $T_s$	Test condition	Alternative test condition
$T_s \leq 70\text{ }^{\circ}\text{C}$	672 <sup>0</sup> <sub>+30</sub> h at $(90 \pm 5)\%$ RH, at $T_s + 20 \pm 2\text{ K}$ (but not less than 80 °C test temperature)	
$70\text{ }^{\circ}\text{C} < T_s \leq 75\text{ }^{\circ}\text{C}$	672 <sup>0</sup> <sub>+30</sub> h at $(90 \pm 5)\%$ RH at $T_s + 20 \pm 2\text{ K}$	504 <sup>0</sup> <sub>+30</sub> h at $(90 \pm 5)\%$ RH at $(90 \pm 2)\text{ }^{\circ}\text{C}$ followed by 336 <sup>0</sup> <sub>+30</sub> h dry at $T_s + 20 \pm 2\text{ K}$
$T_s > 75\text{ }^{\circ}\text{C}$	336 <sup>0</sup> <sub>+30</sub> h at $(90 \pm 5)\%$ RH at $(95 \pm 2)\text{ }^{\circ}\text{C}$ , followed by 336 <sup>0</sup> <sub>+30</sub> h dry at $T_s + 20 \pm 2\text{ K}$	504 <sup>0</sup> <sub>+30</sub> h at $(90 \pm 5)\%$ RH at $(90 \pm 2)\text{ }^{\circ}\text{C}$ followed by 336 <sup>0</sup> <sub>+30</sub> h dry at $T_s + 20 \pm 2\text{ K}$

At the conclusion of the test according to Table 1, the enclosures or parts of enclosures in non-metallic materials that were tested shall be subjected to  $(20 \pm 5)\text{ }^{\circ}\text{C}$  at  $(50 \pm 10)\%$  relative humidity for 24 h 0 +48 h, and then immediately followed by the thermal endurance to cold test. (Standard IEC 60079-0., 2013).

The test values given in Table 1 include two test conditions. The conditions shown in the 2nd column were used in previous editions of this standard and allow previously obtained test results to remain valid for this edition.

The conditions shown in the 3rd column have been added to allow testing at temperature/humidity conditions that are more readily achieved, although at an increased test time. (Standard IEC 60079-0., 2013).

It is generally acknowledged that glass and ceramic materials are not adversely affected by the thermal endurance to heat test, and testing may not be necessary. (Standard IEC 60079-0., 2013).

### 2.2. Thermal endurance to cold

The thermal endurance to cold shall be determined by submitting the enclosures and parts of enclosures of non-metallic materials, on which the type of protection depends, to storage for 24 h 0+2 + in an ambient temperature corresponding to the minimum service temperature reduced according to standardized requests. (Standard IEC 60079-0., 2013) (Standard IEC 60079-7., 2016).

It is generally acknowledged that glass and ceramic materials are not adversely affected by the thermal endurance to cold test, and testing may not be necessary. (Standard IEC 60079-0., 2013) (Standard IEC 60079-7., 2016).

## 3. Results obtained

During the process of certification of a equipment used in potentially explosive atmosphere (Pasulescu et al., 2017a, and Pasulescu et al., 2017b), at National Institute for Research and Development in Mine Safety and Protection to Explosion – INSEMEX laboratories are performed thermal endurance tests. The equipment is tested in the climatic chamber.

After the equipment was submitted to thermal endurance to cold and to heat, it was tested for resistance to impact. Following this test, the equipment did not suffer deformations or cracks, so it can be safely used in explosive atmosphere for which it was designed. This test is essential in the process of certification of equipment used in explosive areas.





Fig.1. Climatic chamber



Fig.2. Lamps subjected to thermal endurance tests

Table 2 Results of the resistance to impact test.

Equipment subjected to resistance to impact test.	The height from which the equipment is hit	Impact energy (m*g*h)	Results
Lamp used in potentially explosive atmosphere	0.4 m	1 kg*9.8m/s <sup>2</sup> *0.4m =3.92 Joul	The equipment has not been deformed or cracked

Following numerous applications for product certification received by INSEMEX, it has been decided to purchase a larger climate chamber to test a wide range of products.

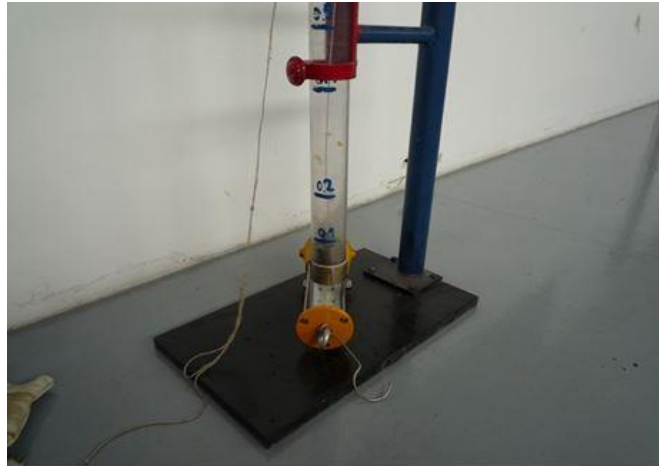


Fig.3. Lamp subjected to resistance to impact test.

#### 4. Conclusions

To protect people who work in explosive environments, it is important that equipment operating in such areas to comply with the requirements in force, and be properly maintained.

According to the requirements in force, in the process of certification of Ex equipment call of them must be tested in order to verify if the explosion protection characteristics are maintained at their level. In this paper was revealed the importance of thermal endurance tests performed on equipment used in potentially explosive atmosphere. Also after the studies made in the laboratories, it became necessary to acquire a large climate chamber, which will be done within this year.

#### Acknowledgements

This article uses the data obtained within the project PN 18 17 02 01 of the „Nucleu” Program developed with the help of ANCSI.

#### References

- Fotău D., *Doctoral thesis-Researches regarding the increase of operational safety of electrical-mechanical equipment used in potentially explosive atmospheres*, University of Petroșani, Romania, (2016).
- Fotău D., Burian. S., Magyari. M., Moldovan. L., Rad. M., Tests carried out on cable entries and their importance within the certification process of explosion-proof equipment, *17 International Multidisciplinary Scientific Geo Conference, SGEM 2017*, Albena, Bulgaria, vol.13, pp 847-852, (2017).
- Ghicioi E., Gaman. G., Vlasin. N., Păsculescu. V., Gabor. D., *Prevention of accidental pollution with combustion gases after the occurrence of explosion*, Environmental Engineering and Management Journal, Romania, vol. 16, pp 1289-1294, (2017).
- Păsculescu, D., Lupu, L., Păsculescu, V., Inisconi, I., Suvar, M., *Study of electrocution hazards in three-phase electrical networks with ground-isolated neutral point*, Environmental Engineering and Management Journal, Vol. 11, No. 7, pp. 1267-1271, (2012).
- Păsculescu, V.M., Vlasin, N.I., Florea, D., Suvar, M.C., *Improving the quality of the process for selecting electrical equipment intended to be used in potentially explosive atmospheres*, Quality-Access To Success, Vol. 18, S1, pp. 97-102, (2017)
- Păsculescu, V.M., Vlasin, N.I., Suvar, M.C., Lupu, C., *Decision support system for managing electrical equipment used in hazardous atmospheres*, Environmental Engineering and Management Journal, Vol. 16, Issue 6, pp. 1323-1330, (2017).
- Standard IEC 60079-0 - *Explosive atmospheres - Part 0: General requirements*, (2013).
- Standard IEC 60079-1 - *Explosive atmospheres - Part 1: Equipment protection by flameproof enclosure "d"*, (2015).
- Standard IEC 60079-7 - *Explosive atmospheres - Part 7: Equipment protection by increased safety "e"*, (2016).

## Considerations about the encapsulated equipment tests

Cosmin Colda<sup>a\*</sup>, Sorin Burian<sup>a</sup>, Marius Darie<sup>a</sup>, Tiberiu Csaszar<sup>a</sup>, Danut Grecea<sup>a</sup>

<sup>a</sup>National Institute for Research and Development in Mine Safety and Protection to Explosion - INSEMEX, 32-34 G-ral Vasile Milea Street, Petrosani, ROMANIA

---

### Abstract

The use of electrical energy in potentially explosive atmospheres involves various particularities, fact for which there have been raised a lot of issues concerning the design, construction and exploitation of electrical equipment and installations intended to be used in these atmospheres. This paper presents the explosion protection principles implemented for the type of protection encapsulation “m” which are based on the adoption of certain separations between the encapsulated circuits and the other circuits, by including them in a compound. The paper describes the test methodologies for explosion-proof electrical equipment with type of protection encapsulation “m”.

*Keywords:* type of protection; encapsulation; electrical equipment; compound; type test.

---

### 1. Introduction

In health and security domain, it is noted a rising trend of the security level in conformity with scientific knowledge state and with taking in consideration of the new risk factors due to economic development. It also follows the same trend the protection of low currents installations utilized in workplaces with risk of explosives atmospheres. Directive 2014/34/EU states that equipment and installations utilized in explosive atmospheres must have compatible specifications with the ones of explosive atmosphere there are about to work, (Burian et al., 2007).

In order to evaluate the equipment for protection to explosion, encapsulation type, one has to follow an investigation process of the equipment in terms of its conformity with relevant standard requirements for protection to explosion, (Darie et al., 2015). As to evaluate the electric equipment for protection to explosion, type encapsulation “m”, the current trend is to increase the evaluation share through applicable calculus on the equipment, using tables and diagrams presented in applicable standards SR EN 60079-0; SR EN 60079-18. This paper follows the study and assessment of the requirements concerning absorption test for electric equipment with type “m” protection.

### 2. Encapsulated equipment, technical documentation, description, generalities

The conformity assessment of technical documentation for equipment used in potentially explosive atmospheres is made in accordance with Directive 2014/34/EU, annex 3. The documentation submitted to the notified body must include the following. (EN Directive, 2014):

- a general type-description;
- design and manufacturing drawings and layouts of components, subassemblies, circuits, etc.;
- descriptions and explanations necessary for the understanding of said drawings and layouts and the operation of the product;
- a list of the standards referred to in Article 5, applied in full or in part, and descriptions of the solutions adopted to meet the essential requirements of the Directive where the standards referred to in Article 5 have not been applied;
- results of design calculations made, examinations carried out, etc.;
- tests reports.

---

\* Corresponding author. Tel.: +40763618571; fax: +40254546277  
E-mail address: cosmin.colda@insemex.ro.

The notified body shall:

- examine the technical documentation, verify that the type has been manufactured in conformity with the technical documentation and identify the elements which have been designed in accordance with the relevant provisions of the standards referred to in Article 5, as well as the components which have been designed without applying the relevant provisions of those standards;
- perform or have performed the appropriate examinations and necessary tests to check whether the solutions adopted by the manufacturer meet the essential requirements of the Directive where the standards referred to in Article 5 have not been applied;
- perform or have performed the appropriate examinations and necessary tests to check whether these have actually been applied, where the manufacturer has chosen to apply the relevant standards;
- agree with the applicant the location where the examinations and necessary tests shall be carried out.

Equipment/installations of low currents are those equipment / electrical installation in which the electric components utilized for info transfer, for mini-macro movements also for the components whose nominal voltage doesn't exceed 11 kV, are included in a compound.

A brief review on these protection type encapsulation installations following their objectives: equipment and installations in automation field, data communication, interlocks, controls; Monitoring and alarm equipment and installations for water leaks, explosive and toxic gases, respectively for fire; equipment and installations for access control, warning device for surveillance; equipment and installations for (video) intercom, telephony and sound; equipment and installations for data transmission and VDI; equipment and installations for data cable CATV and other circuit parts (Figure 1).

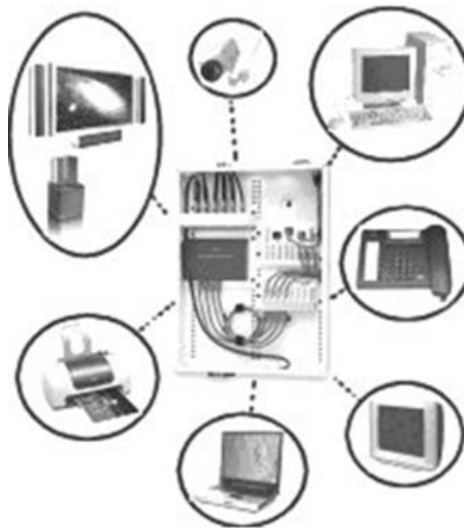


Fig. 1. Encapsulated equipment and electrical installations

The protection type in which the parts that can ignite an explosive atmosphere either by spark or by heating, are included in a compound, so that the given explosive atmosphere can't be lit in normal operating conditions is referred to as encapsulation "m".

The electric encapsulated "m" equipment can be with:

- a) protection level "ma" (EPL "Ma, Ga, Da"),
- b) protection level "mb" (EPL "Mb, Gb, Db") or
- c) protection level "mc" (EPL "Gc, Dc").

### 3. Tests on the apparatus

The test sequence and number of samples are shown below (SR EN (IEC) 60079-18, 2015):

#### 3.1. Maximum temperature

A sample of "m" equipment shall be subjected to a type test to ensure that:

- a) the temperature limits are not exceeded in normal operation;
- b) for level of protection "ma" and "mb" the maximum surface temperature is not exceeded under fault conditions.

For "m" equipment without an external load, the test shall be carried out in accordance with the temperature measurements of IEC 60079-0 taking into account the supply conditions.

### 3.2. Thermal endurance test

#### 3.2.1. Thermal endurance to heat

- for level of protection “ma” and “mb”, the test shall be carried out in accordance with IEC 60079-0. The temperature to be used as the reference service temperature for the test shall be either:

a) the maximum surface temperature of the test sample under normal operation plus 20 K;

or

b) the maximum temperature at the component surface in the compound under normal operation, see 6.2.2.

- for level of protection “mc”, the test shall be carried out in accordance with IEC 60079-0.

The temperature to be used as the reference service temperature for the test shall be the maximum surface temperature under normal operation.

#### 3.2.2. Thermal endurance to cold

The test shall be carried out in accordance with IEC 60079-0.

After each test the sample shall be subjected to a visual inspection. No visible damage to the compound that could impair the type of protection shall be evident, for example cracks in the compound, exposure of encapsulated parts, failure of adhesion, inadmissible shrinkage, discoloration, swelling, decomposition or softening. A discoloration on the surface of the compound is permissible (for example oxidation in the case of epoxy resin).

### 3.3. Dielectric strength test

The test shall be carried out on the following arrangements of circuits as applicable:

a) between galvanically isolated circuits;

b) between each circuit and all earthed parts;

c) between each circuit and the surface of the compound or the non-metallic enclosure that, if necessary, can be clad with a conductive foil.

For arrangement a), the voltage U to be used shall be the sum of the rated voltages of the two circuits being tested and for arrangements b) and c), the voltage U to be used shall be the rated voltage of the circuit being tested.

For arrangement b), circuits that contain transient suppression components connected between the circuit and the earthed parts, a special test sample without these components shall be permitted for the type test.

Dielectric strength shall be verified by test:

- either as given in a relevant industrial standard for the individual items of electrical equipment or,
- at the test voltage according to 1) or 2) below, and increased steadily within a period of not less than 10 s until it reaches the prescribed value, and it shall then be maintained for at least 60 s without dielectric breakdown occurring.

The test voltage shall be increased steadily within a period of not less than 10 s until it reaches the prescribed value, and it shall then be maintained for at least 60 s.

### 3.4. Cable pull test

The test shall be carried out on one sample, previously unstressed and at  $21\text{ °C} \pm 2\text{ °C}$ .

A further test sample shall be subjected to the cable pull test after conditioning at the maximum temperature at the cable entry point. The tensile force (in Newton) applied shall either be 20 times the value in millimeters of the diameter of the cable or 5 times the mass (in kilograms) of the “m” equipment, whichever is the lower value. This value can be reduced to 25 % of the required value in the case of permanent installations. The minimum tensile force shall be 1 N and the minimum duration shall be 1 h. The force shall be applied in the least favorable direction.

After testing, the sample shall be subjected to a visual inspection. Visible displacement of the cable, which affects the type of protection, shall not be evident. No damage to the compound or cable that could impair the type of protection shall be evident, for example, cracks in the compound, exposure of the encapsulated components or failure of adhesion.

### 3.5. Pressure test for Group I and Group II electrical equipment

For level of protection “ma” with any individual free spaces between 1 cm<sup>3</sup> and 10 cm<sup>3</sup> and level of protection “mb” with any individual free spaces between 10 cm<sup>3</sup> and 100 cm<sup>3</sup>, two test samples shall be prepared with a pressure connection. Where there is more than one free space of a size requiring testing, the pressure test shall be carried out simultaneously in all those free spaces. The pressure test shall be carried out on samples that have already been submitted to the thermal endurance tests. The test shall be carried out with a pressure as shown in Table 1 applied for at least 10 s.

Table 1. Test pressure

Minimum ambient temperature °C	Test pressure kPa
$\geq -20$ (a)	1 000
$\geq -30$	1 370
$\geq -40$	1 450
$\geq -50$	1 530
$\geq -60$	1 620

a) This covers equipment designed for the standard ambient temperature range specified in IEC 60079-0.

As an alternative for 'mb' equipment if the component with a free space up to 100 cm<sup>3</sup>, prior to encapsulation, passes the Leakage test on sealed devices specified in IEC 60079-15 (without the conditioning, voltage, or dielectric withstand testing) it can be encapsulated without requiring the pressure test. After testing, the samples shall be visually inspected. No compound damage (such as cracks in the compound, exposure of the encapsulated components or failure of adhesion) that could impair the type of protection shall be evident. For constructions that are permitted to have no thickness of compound between a free space and a non-metallic enclosure wall, there shall also be no damage to the non-metallic enclosure wall(s).

### 3.6. Sealing test for built-in protective devices

The test is to be performed on five samples. With the test samples at an initial temperature of  $(25 \pm 2)$  °C, they are suddenly immersed in water at a temperature of  $(50 \pm 2)$  °C to a depth of not less than 25 mm for at least 1 min. The devices are considered to be satisfactory if no bubbles emerge from the samples during this test.

## 4. Conclusion

Being a part of IECEx system, means implementing some appropriate methods for water absorption testing in testing laboratory. This paper presents the main tests for electrical apparatus with encapsulation protection type. Analysis specific requirements of the standard SR EN 60079-18 on the evaluation equipment with type of protection encapsulation "m" highlighted compound role in the determination of applicable defects in the phase of explosion protection evaluation. Presentation in the requirements of water absorption test for explosion-protected equipment through the types of protection encapsulation "m", being one of the basis tests for these.

The increased complexity of the circuits of the equipment involved in the production process using a compound and conceiving with regard to protection from explosion due to thermal effects to which they may be subjected to. Standardized values imposed by the requirements of isolation distances resulting from the simplified assessment process are superior to those which can be implemented which often leads to rejection of rated equipment.

The aim is to study different types of compound to satisfy the mechanical and thermal resistance, to dissipate the thermal effects caused by overheating the electric and electronic components included in the compound without them affecting the electric equipment safety of use. This aspect is primarily important due to a high number of equipment which operates in explosive atmospheres hazardous areas where the temperature varies between  $-30^{\circ}\text{C}$  ÷  $+50^{\circ}\text{C}$ .

### Acknowledgements

This article uses the experimental results obtained within the project 16 43 02 16 / 22N/2016 and PN 18 17 02 01 of the „Nucleu” Program developed with the help of ANCSI.

### References

- Burian S., Ionescu J., Darie M., Csaszar T., Andriş A., *Requirements for Installations in Areas with Explosive Atmosphere, Other than Mines, (in Romanian)*, INSEMEX – Petrosani Publishing House, Romania, (2007).
- Darie, M., Burian, S., Ionescu, J., Csaszar, T., Moldovan, T., Colda, C., Moldovan, C., Andriş, A., *Investigation of air humidity influence over the ignition sensitivity of gaseous explosive atmospheres from the underground of firedamp mines*. The Sixth Balkan Mining Congress Balkanmine 2015 Petrosani, Romania, (2015).
- Directive 2014/34/EU of the European Parliament and of the Council of 26 February 2014 on the harmonisation of the laws of the Member States relating to equipment and protective systems intended for use in potentially explosive atmospheres (recast) On line at: [http://ec.europa.eu/DocsRoom/documents/16402/ attachments/ 1/translations /en/renditions/native](http://ec.europa.eu/DocsRoom/documents/16402/attachments/1/translations/en/renditions/native)), (2014).
- SR EN (IEC) 60079-18:2015. *Explosive atmospheres. Equipment protection by encapsulation "m"*, (2015).

# Influence of the volume and geometrical shape of large electric motor enclosures on the explosion pressures when tested in explosive mixtures

Mihai Magyari<sup>a</sup>, Sorin Burian<sup>a</sup>, Lucian Moldovan<sup>a</sup>, Dragoş Fotău<sup>a</sup>, Marcel Rad<sup>a\*</sup>

National Institute for Research and Development in Mine Safety and Protection to Explosion – INSEMEX, 32-34 G-ral Vasile Milea street, Petroşani, 332047, Romania

## Abstract

The purpose of the paper is to perform a thorough study upon the way in which the internal volume, the dimensions, the geometrical shape, as well as the internal arrangement of explosion protected flameproof large rotative electrical machine enclosures, influence the maximum explosion pressures and the explosion pressure development, while testing in explosive mixtures of gases and vapors. The researches conducted in the specialized Laboratory of INSEMEX Petrosani have identified as causes for the occurrence of pressure peaks in the case of large electric motor enclosures, the extremely great internal volume, the geometrical shape of motor enclosures and the very complex internal arrangement of these motors, having in mind the motor manufacturers for the chemical and petrochemical industry trend to manufacture ever more complex geometrical shape motors.

**Keywords:** electric motor; explosive atmospheres; flameproof; pressure.

## 1. Introduction

As widely known, in case of flameproof electric motors as well as in case of most of the technical equipment in general, design and manufacture exceeded long time ago the stage when the manufacturers used to apply their own design methods. At present, the design and manufacture methods for the flameproof type of protection are fully determined by the provisions in the standard (Romanian Standard, 2015), according to which all new motors are manufactured. The electric motors with type of protection flameproof enclosure have to withstand the following type tests and verifications, in order to be certified having in view to their placing on the market: reference pressure determination and overpressure test and test for non-transmission of an internal ignition (Government Decision, 2016; Romanian Standard 2015; Romanian Standard, 2013). The most important subassemblies of flameproof enclosure motors that endorse the type of protection are: stator casing, shields, rotor, fan and fan hood, terminal box, terminal box cover, as shown in Fig.1.

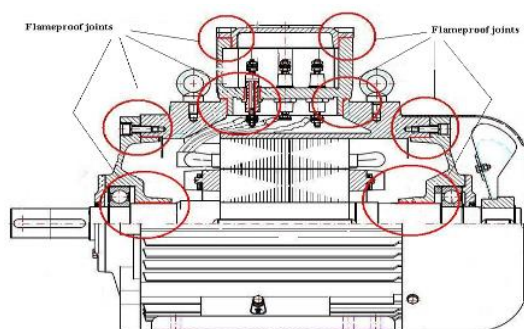


Fig. 1. Flameproof enclosure motor assembly

\* Corresponding author. Tel.: +4-025-454-1621; fax: +4-025-454-6277.  
E-mail address: marcel.rad@insemex.ro.



## 2. Factors which influence the explosion pressures inside the flameproof enclosure

The maximum internal pressure developed due to the ignition of an explosive mixture inside the motor enclosure depends directly of the volume of gases discharged through the flameproof gaps and other discharge devices if present. Still, the flameproof joints of motors cannot be designed for the purpose of discharging the explosion pressures and they have to be secured to the safety dimensions at which the ignition transfer to the surrounding environment is prevented (Wolfhard and Bruszak, 1960).

### 2.1. Static pressure

In case there is no anticipation for the occurrence of higher than normal explosion pressures for the motor, the manufacturer will carry out the routine overpressure test at 20 bar, for one minute maximum, for each motor enclosure.

Having in mind that the maximum explosion pressures as a result of pressure pilling cannot be foreseen, the motor enclosure should be designed assuming that pressure pilling will not occur and the manufacturer should have in mind the recommendations regarding the avoidance of this phenomenon, described in the following paragraphs.

### 2.2. Dynamic pressure

Figure 2 presents an example of pressure diagram normally obtained in a group II C flameproof motor enclosure during the maximum pressure determination test.

Normally, the explosion pressures are measured in three distinct areas during each test: at each of the end shields of the motor and under the terminal plate of the motor, having in mind that from the experience of the testing laboratory, these areas have been responsible for generating the maximum explosion pressures, regardless of the explosion test mixture (Magyari, 2017), (Magyari, 2015).

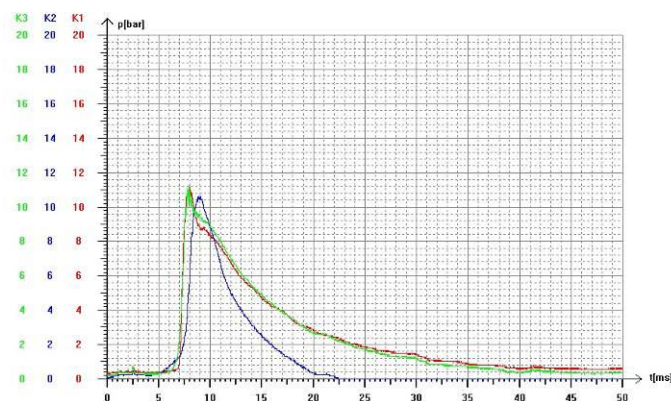


Fig. 2. Example of explosion pressure diagram, using 3 pressure transducers setup

In order to analyze the response of the enclosure when submitted to an internal explosion, it is necessary to know the maximum explosion pressure, the pressure rise time and the pressure persistence time.

#### 2.2.1 Maximum explosion pressure

Usual pressure values measured in the laboratory are 14 or 15 bar, on different types of motor enclosures, provided there is no pressure pilling phenomenon. Thus, the designer of the motor enclosure should have in mind a value of 20 – 22 bar for the enclosure, as a reasonable figure, unless there are solid arguments for designing the enclosure for an increased pressure.

For example, the dynamic pressure foreseen for the designing the motor enclosure can be increased if the particular geometrical shape of the enclosure is expected to generate increased pressure values, due to pressure pilling (Magyari, 2017), (Magyari et al., 2015).

#### 2.2.2 Pressure rise time

In order to determine the minimum pressure rise time, it is useful to use the maximum increase explosion pressure rate ( $dp/dt$ ). The use of a minimum determined pressure increase rate, for example in the case of spherical enclosures, will not guarantee a resulting minimum pressure increase time for all types of enclosures, but the use of an estimated minimum pressure increase time is conservative, that is why this approach is suitable for designing enclosures having a different geometrical shape than spherical, such as is the case of electrical motor enclosures (Magyari et al., 2011).

### 2.2.3 Pressure pilling

The term “pressure pilling” as used in the paper, refers to a pressure increase in one of the motor enclosure compartments, above the values normally expected to occur in that compartment, if that subdivision did not exist. This increase of the explosion pressure can be considered as abnormal as compared to the pressure resulted from a burning process in a constant volume, having an initial pressure of the testing mixture equal or as equal to atmospheric pressure (Magyari, 2017), (Magyari et al., 2015), (Magyari, 2015).

### 3. Main causes for pressure peaks occurrence inside flameproof enclosures

The causes for the occurrence of high pressure peaks in the case of large electrical motor enclosures are the extremely large internal volume (of hundreds and thousands of liters of explosive mixture), the geometrical shape of the motor enclosures, having in mind the latest tendency of motor manufacturers for the chemical and oil and gas industry to manufacture motors having ever more complex geometrical shapes, due to the cooling and mounting means, as well as the internal arrangement of these motors, which differ from the classical ones and from small frame size motors. The existence of several cooling fans, inside and outside of the large motor enclosures, as well as the cooling pipes designed to provide an efficient cooling of these motors having high and very high power, result in an extremely complex and complicated inner configuration of these motors, thus generating a different explosion behaviour from the usual one, with much higher pressure peaks and smaller pressure rise times than normally envisaged (Magyari, 2017).

So far it is unknown for sure the extent to which the geometrical shape, the internal arrangement, the location of the ignition source and its nature, the influence of the explosive testing mixture can be used in order to be able to predict when these pressure peaks are likely to occur and if so, what the resulting pressures will be.

The main causes for the occurrence of pressure peaks in the case of large rotating electrical machines:

- The geometrical shape of the motor enclosure;
- The internal arrangement / division of the motor enclosure;
- The type of gas used and the test mixture concentration;
- The test mixture ignition source;
- Pre compression of the testing mixture;
- Flame front acceleration and flame front instability.

#### 3.1. The geometrical shape of the motor enclosure

The geometrical shape of the motor enclosures plays an important role especially if the ratio between the length of the enclosure and the cross-sectional dimensions is significant. In this case, when the burning is initiated from one end side of the motor, the flame front can be accelerated across the length of the enclosure, being capable even of making the transition from deflagration to detonation in certain extreme cases.

Figure 3 shows 2 examples of large electrical motors having standardized geometrical shapes, whose designs has been checked in the course of the time as being suitable for successful testing in explosive air – gas mixtures. The first example is that of a motor completely designed in flameproof enclosure type of protection – both the stator of the motor and the terminal boxed are Ex d; the second example is that of an Ex d e motor – the stator of the motor is Ex d and the terminal boxes are Ex e increased safety type of protection (Magyari, 2017).

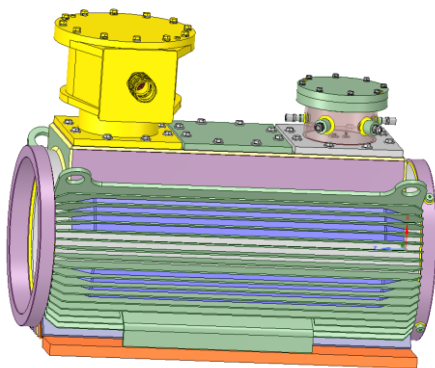


Fig. 3. (a) Ex d II electric motor

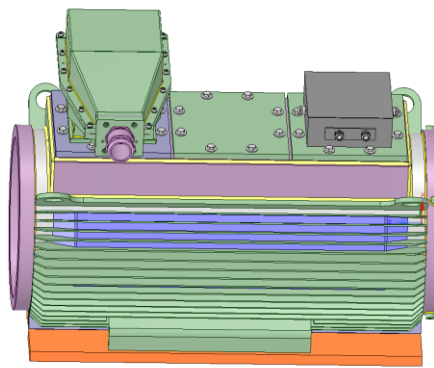


Fig. 3. (b) Ex d e II electric motor

### *3.2. Motor enclosure subdivision*

The motor enclosure subdivision is one of the main causes for pressure peaks occurrence. These pressure peaks occur mostly in the smaller volume subdivision after the ignition took place in the higher volume subdivision. The small surfaces or the passages which connect the two subdivisions increase the likelihood of pressure peaks occurrence. If there are a series of subdivisions connected to each other, the explosion pressure will tend to increase as the flame front propagates from one subdivision to another, reaching the maximum value in the last subdivision (Magyari, 2017), (Magyari et al., 2015).

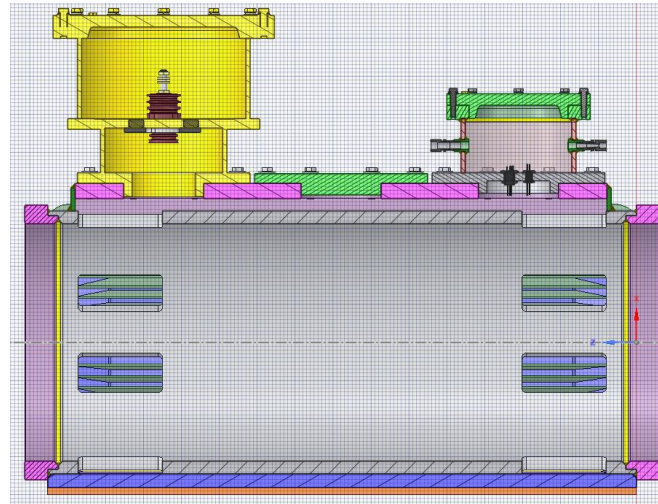


Fig. 4. (a) Internal arrangement in an Ex d II electric motor

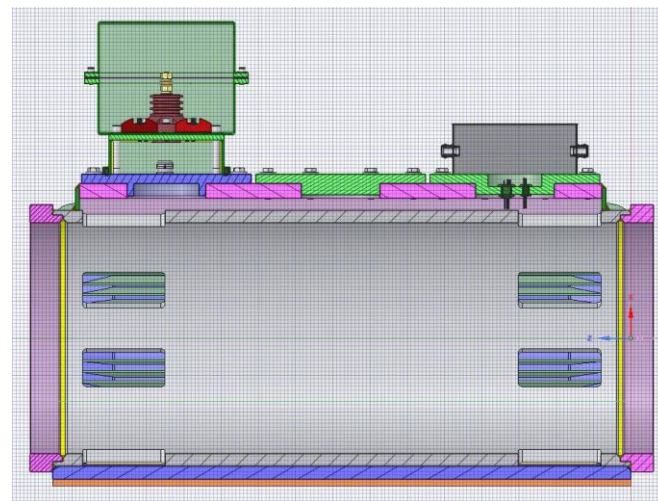


Fig. 4. (b) Internal arrangement in an Ex d e II electric motor

### *3.3. The type of gas used and the explosive mixture concentration*

Gases having a greater explosion potential (such as is the case of hydrogen and acetylene), can produce higher explosion pressures and have a higher tendency to generate higher explosion peaks; also, a concentration which is near to the stoichiometric concentration is likely to result in much higher explosion pressures (Magyari, 2015).

### *3.4. Ignition source*

High power ignition sources generate higher explosion pressures than the normal 12 V ignition sources used in the laboratory for the ignition of the explosive test mixture. An ignition source such as an electrical arc, whose energy is far greater than that of a 12 V sparking plug, used in the laboratory, will always produce higher explosion pressures.

Also, the location of the ignition source can have an influence on the explosion pressure values. The location of the ignition source in the central area of an ordinary enclosure seems to generate the highest explosion pressures; but in the case of higher length enclosures (such as is the case of electric motors), the ignition at one of the end sides of the motor will lead to the occurrence of the highest explosion pressures (Magyari, 2017), (Magyari 2015), (Magyari et al., 2015).

### 3.5. Pre compression of the explosion testing mixtures

The phenomenon of pre compression of the testing mixture occurs usually in the the case of subdivided enclosures, such as is the case of motor enclosures or in the case of interconnected enclosures. Igniting in one of the enclosure subdivision, especially if we are talking about the higher volume subdivision, is likely to produce higher than the ambient pressure initial pressure in the other subdivision of the enclosure. The final values of the explosion pressures are a direct function of the testing mixture pre compression, regardless of the causes which are responsible for the occurrence of the pre compression of the testing mixture (Magyari, 2017).

As regards design solutions, in case subdivision cannot be avoided – the case of motor enclosures (and not only), then the pre compression in the second subdivision, before the ignition of the testing mixture takes place in it, can be estimated as being the final explosion pressure in the first subdivision (Wolfhard and Bruszak, 1960), (Magyari, 2017).

For these considerations, the value of the initial pressure in the second subdivision is:

$$p_i = p_a \times V_1 / (V_1 + V_2) \quad (1)$$

$p_a$  = atmospherical pressure;

$V_1$  = volume of the first subdivision;

$V_2$  = volume of the second subdivision.

This equation has the role to indicate the value of the pressures in the worst case scenario that can be produced because of pre compression and is too conservative for normal designing of enclosures. Too high pressure values obtained by calculus in the case of subdivided enclosures should encourage apparatus designers either to change the equipment design or to have it tested effectively in explosive test mixtures in order to establish more realistic final explosion pressure values that can occur.

### 3.6. Flame front acceleration and flame front instability

Flame front acceleration can be caused by several factors. These include the acceleration induced due to the mixture flow, the turbulence of the mixture and the flame front instability. The acceleration of the gas flow can occur at the openings and passages which connect the enclosure subdivisions. It can also be produced by the turbulence generated by certain obstacles which add resistance in the mixture flow way or by the flame front instability due to acoustic resonance (usually associated with ventilation, during motor running) and due to normal differences existing at the interface of the burned and unburned mixture (Magyari et al., 2015).

Clearly, the designer will not be able to eliminate the required apparatus inside the enclosure. The designer has to focus mainly on avoiding enclosure subdivision (when possible) by carefully arranging the inner apparatus and, in case enclosure subdivision cannot be avoided, the designer has to eliminate the obstacles which are not necessary or the restrictions on the passages between different enclosure subdivisions (Magyari, 2017), (Magyari et al., 2011).

## 4. Conclusions

Applying these considerations by manufacturers of explosion protected apparatus would result in an increased likelihood that these motors will successfully pass the particularly severe type tests, from the first stage of motor design project, thus making later modifications on the motor's constructive project unnecessary should the motor fail these type tests, fact that would transpose into an increased time required for finalizing the certification project, implicitly increased certification costs - which represents an essential criterion in the present economical framework where local Ex motors manufacturers have to compete on the European Union market with well known manufacturers from developed countries.

## Acknowledgments

This paper was developed within the NUCLEU - Programme, carried out with the support of MCI, project no. PN-16-43-02-11 and project no. PN 18-17-02-01.

## References

- Magyari, M., *Development of the installation for testing in explosive mixtures, for performing specific type tests, in case of flameproof electric motors of large dimensions*, (in Romanian), project no. PN 16-43-02-11, Phase 1: Study concerning the manner in which volume, dimensions and shape of flameproof enclosures of electric motors of large dimensions influences their behaviour during type tests in explosive mixtures and acquisition of equipment and devices for performing specific type tests for electric motors of large dimensions, INSEMEX Research study, Petrosani, Romania, (2017).
- Magyari, M., *Improvement of the laboratory test stand in order to perform tests in explosive mixtures for electrical motors with flameproof enclosure type of protection during their operation*, (in Romanian), project no. PN 07-45-02-54, Phase 1: Study on the manner in which the turbulence of the explosive mixture influences explosion pressures and acquisition of equipment required for performing tests for electric motors during their operation, INSEMEX Research study, Petrosani, Romania, (2015).
- Magyari, M., Burian, S., Moldovan, L., Fotau, D., Colda, C., Determination of the flameproof performances during verifications and type tests of flameproof "d" electric motors in normal operation, *7<sup>th</sup> International Symposium on Occupational Health and Safety – SESAM*, Vol. I, pp. 257-266, Poiana Braşov, Romania, (2015).
- Magyari, M., Burian, S., Friedmann, M., Moldovan, L., Factors affecting the flameproof motor enclosures design, to pass the tests in explosive gas mixtures, *5<sup>th</sup> International Symposium on Occupational health and Safety – SESAM*, pp. 250-259, Sinaia, Romania, (2011).
- Romanian Standard, *SR EN 60079-1 Explosive atmospheres - Part 1: Equipment protection by flameproof enclosures "d"*, Romanian Association for Standardization – ASRO, Bucharest, Romania, 2015.
- Romanian Standard, *SR EN 60079-0 Explosive atmospheres - Part 0: Equipment – General requirements*, Romanian Association for Standardization – ASRO, Bucharest, Romania, (2013).
- Wolfhard, H.G., Bruszak, A.E., *The passage of explosions through narrow cylindrical channels*, *Combustion and Flame*, Vol. 4, pp. 149-159, (1960).
- Government Decision, *Government Decision no. 245 from 06.04.2016 on the placement on the market of equipment and protective systems intended for use in potentially explosive atmospheres*, (in Romanian), Romanian Government, (2016).

## Aspects on small components ignition test using explosive gas mixtures

Adriana Andriș<sup>a\*</sup>, Constantin Sorin Burian<sup>a</sup>, Marius Darie<sup>a</sup>, Tiberiu Atila Csaszar<sup>a</sup>, Iosif Lucian Moldovan<sup>a</sup>, Cosmin Ioan Colda<sup>a</sup>, Dănuț Nicolae Grecea<sup>a</sup>, Gabriela Pupăzan<sup>a</sup>

<sup>a</sup>National Institute for Research and Development in Mine Safety and Protection to Explosion – INSEMEX Petroșani, 32-34 G-ral Vasile Milea Street, Petroșani, zip code 332047, Hunedoara County, Romania

---

### Abstract

Avoiding the ignition of an explosive atmosphere by the equipment intended for use in such atmospheres is achieved by applying one or more types of explosion protection specific to this equipment.

Certification of electrical equipment intended for use in potentially explosive atmospheres involves the evaluation and testing of this equipment for the specific application.

The first part of the paper presents the specific requirements to perform the ignition test of flammable mixture by the small components of the electrical equipment intended for use in potentially explosive atmospheres

In the second part of the paper are presented the constructional particularities of the test stand used for the ignition test of the flammable mixture by the small components of the electrical equipment intended for use in potentially explosive atmospheres

The third part of the paper presents the procedure used for functional testing of the test stand.

*Keywords:* Explosive atmospheres; small components; test stand.

---

### 1. Introduction

In order to certify the equipment that is part of a system in explosion-protected construction, it is necessary to evaluate and test them by point of view of explosion risk. This risk must be minimized by the user in order to ensure the safety of people's life and health, as well as to prevent damage to property and, last but not least, damage to the environment.

At European level, the certification of electrical and non-electrical equipment intended for use in explosive atmospheres is carried out in accordance with (Directive 2014/34/EU, 2014), commonly named as the ATEX Directive. Considering the fact that each member state of the European Union has the obligation to harmonize its legislation in this field, at national level the ATEX Directive was fully transposed in national legislation.

Compliance of equipment and protective systems intended for use in potentially explosive atmospheres with harmonized European standards in the field of the (Directive 2014/34/EU, 2014) is a method of assessing the essential health and safety requirements provided in the Directive. Compliance with standards is not mandatory but is generally used to assess products covered by the Directive.

At the world level, the IECEx certification scheme for explosion-proof equipment is the framework for the recognition of assessing and testing of equipment intended for use in potentially explosive atmospheres carried out for their certification in order to operate in such atmospheres. In this case, full compliance with IEC standards is mandatory.

### 2. Specific requirements for evaluation and testing of small components

The assessment and testing of electrical equipment intended for use in explosive atmospheres it is necessary to consider both spark ignition and ignition by thermal effects (Burian et al., 2014).

In the assessment of ignition by thermal effects of the electrical equipment it is necessary to consider the ambient temperatures range in which the equipment will operate, the service temperature of the equipment and the maximum

---

\* Corresponding author. Tel.: + 4-0254-541-621; + 4-0254-541-622; fax: + 4-0254-546-277  
E-mail address: adriana.andris@insemex.ro



surface temperature of the equipment that must not exceed the temperature class assigned to the equipment (IEC 60079-11, 2011).

Small components of electrical equipment intended for use in explosive atmospheres may reach a temperature higher than the assigned temperature class of the equipment during operation. This is permitted according to (IEC 60079-0, 2017) only if the small components do not produce the ignition of the specific flammable mixture when subjected to the ignition test.

Another situation where it is permissible to exceed the temperature class at an ambient temperature of 40 °C is when, depending on the surface area of the small component, the exceeding of the maximum surface temperature is limited to the values in Figure 1:

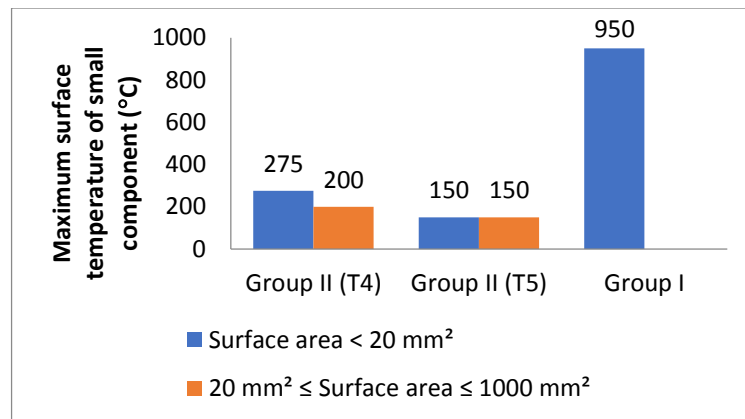


Fig. 1. The maximum permissible surface temperature of the small component at an ambient temperature of 40 °C

Exceeding the temperature class of the equipment by the small components is also permitted if the values for the maximum power dissipated on the component with the surface area  $\geq 20 \text{ mm}^2$  in Figure 2 are not exceeded at the maximum operating ambient temperature.

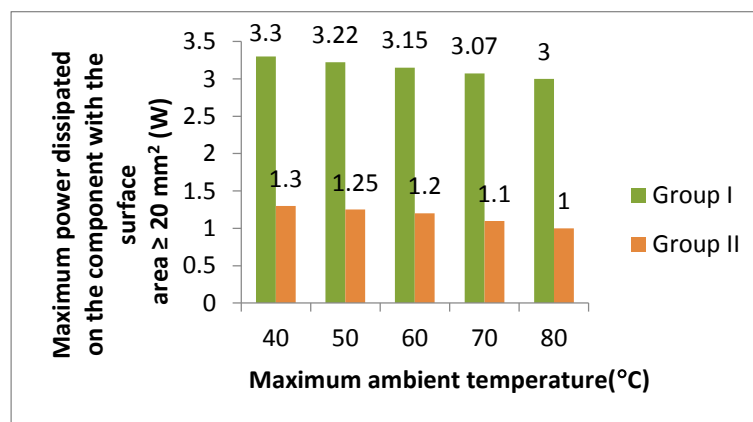


Fig. 2. The variation of maximum power dissipation on component with the ambient temperature

The ignition test for small components is required to demonstrate that in normal operation or fault specified conditions these components are not capable of igniting the flammable test mixture by increasing the surface temperature above the assigned temperature class of the equipment.

For small components with a surface area not exceeding 1 000 mm<sup>2</sup>, their surface temperature may exceed the temperature given by the temperature class marked on the Group II electrical equipment or the corresponding maximum surface temperature for Group I electrical equipment, if there is no risk of ignition due to these surfaces, with a safety margin of

- 50 K for temperature class T1, T2 and T3,
- 25 K for temperature class T4, T5 and T6 and Group I.

During the tests, the safety limit can be ensured by increasing the ambient temperature or by increasing the dissipated power of the component. For methane (Group I) the second option is recommended and the test mixture shall be a homogeneous mixture of between 6,2 % and 6,8 % v/v methane and air.

For temperature class T4, the mixture shall be:

- a homogeneous mixture between 22,5 % and 23,5 % v/v diethyl ether and air, or
- a mixture of diethyl ether and air obtained by allowing the evaporation of a small quantity of diethyl ether inside the test chamber during the ignition test.



The testing of small components may be carried out with the component installed in the equipment as designed and it must be ensured that the test mixture (Andriş et al., 2017) is in contact with the component or with the component mounted in a model that provides representative results.

The component shall be tested in normal operation or in fault conditions leading to reaching the highest surface temperature value. The test must be continued until the thermal equilibrium of the component and the surrounding parts is reached or the temperature of the component decreases.

If a cold flame occurs during the test, it is considered as an ignition. Ignition can be visually detected or by measuring the temperature for example with a thermocouple.

If no ignition occurs during the test, the presence of the flammable mixture must be checked by igniting the mixture by other means.

### 3. Description of the test stand used for the ignition test for small components

To the perform of ignition test for small components from the equipment intended for use in explosive atmospheres, a test stand has been designed whose block diagram is shown in Figure 3.

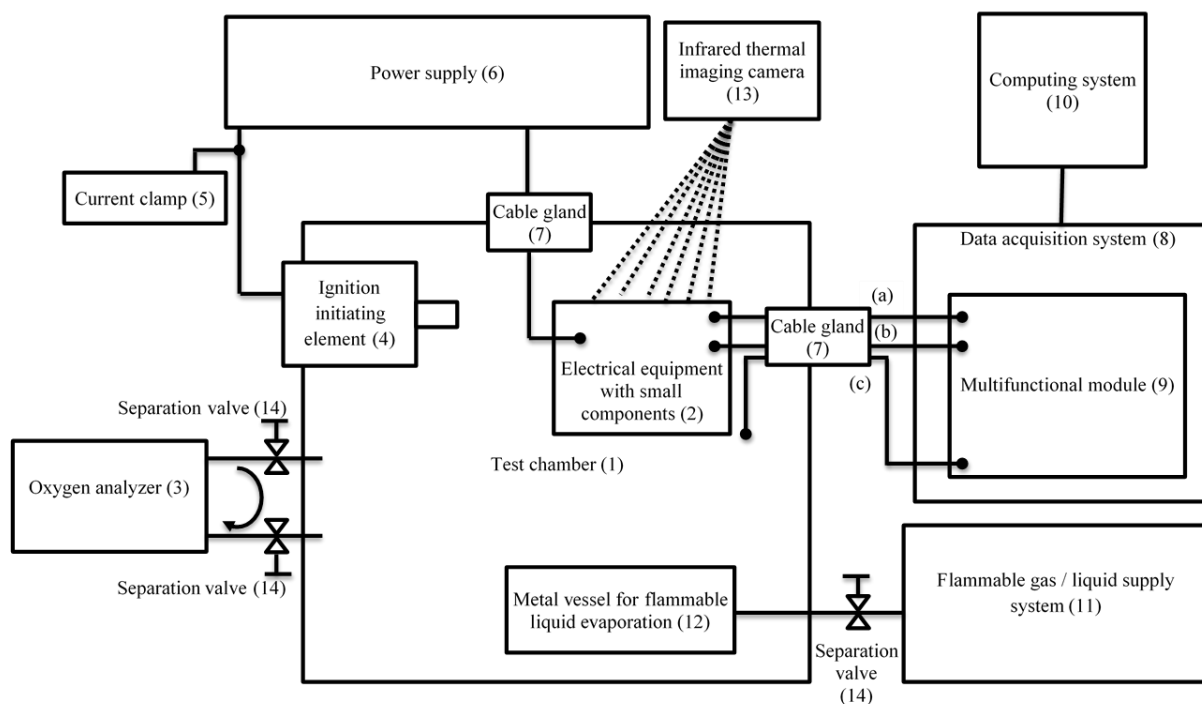


Fig. 3. Block diagram of the test bench for small components from the equipment intended for use in explosive atmospheres

The components of the test stand are as follow:

(1) - test chamber. It is made of metallic material and is provided with two cable glands (7). The equipment with the small components subjected to the test (2) are placed in this test chamber (1), and the test explosive mixture is also carried out here;

(2) - electrical equipment with small components subjected to testing. The object of the test is the small component that heats over the temperature class assigned to the equipment. Testing of small components is done with the component mounted in the equipment as it is designed;

(3) - oxygen analyser. It is used to measure the test mixture. To determine the concentration of the explosive test mixture inside the test chamber (1) measure the concentration indirectly with the oxygen analyser (3);

(4) - ignition initiating element of the test mixture. It is a glow plug powered from the double source (6). The ignition initiating element of the test mixture (4) shall only be used in situations where ignition caused by the heating of the small component (2) does not occur during the test. In these cases, it is necessary to ignite the test mixture by another means, thereby proving the presence and quality of the explosive test mixture within the test chamber (1);

(5) - current clamp placed on the circuit of the initiating element (4) and has the role of confirming the supply of the initiating element to nominal parameters;

(6) - power supply. It is a DC double source supplying both the electrical equipment with the small components which are tested (2) and the ignition initiating element of the test mixture (4);

(7) - cable glands. They are provided on the housing of the test chamber (1) and are intended to facilitate the tight introducing of the electrical conductors for the electrical equipment with the small components which are tested (2), the connection facilities (b) for measuring the electrical parameters in the small components circuit and of thermocouples (a) and (c);

(8) - data acquisition system;

(9) - multifunctional module;

(10) - computing system;

(11) - flammable gas/liquid delivery system. The preliminary quantity of flammable liquid is determined by calculation for a given concentration and introduced through the flammable liquid delivery system (11) into the test chamber (1) and the concentration value is monitored by the oxygen analyser (3);

(12) - metal vessel for flammable liquid evaporation. It is located in the test chamber (1) and is intended to allow evaporation of the amount of flammable liquid introduced by dripping through the delivery system (11);

(13) - infrared thermal imaging camera. It is used to supervise the general thermal regime of the equipment (2) during the test;

(14) - separation valves. After the explosive test mixture has been obtained, the separation valves will close before connecting the electrical equipment with small components (2) to the power supply;

(a), (c) - thermocouples of type K/J for measuring the surface temperature of small components (2) and ambient temperature inside the test chamber (1);

(b) - connection facilities for measuring the electrical parameters in small components circuit.

#### 4. Functional testing of the test stand

The test stand achieved was tested functionally according to the following methodology:

*Step 1:*

- the test conditions regarding the test explosive mixture parameters, the ambient temperature inside the test chamber during the test, and the electrical supply parameters of the equipment with the small components (2) have been established.

A mixture of 23 % v/v diethyl ether in air, obtained by evaporating the flammable substance introduced into the test chamber (1) through the delivery system (12), was used. The amount of liquid diethyl ether that was introduced into the test chamber was calculated according to formula from relation (1) resulting a value of 6,5 ml:

$$V_l = \frac{P_{atm} \cdot c_{subs} \cdot V_{cam} \cdot \mu_{subst}}{R \cdot T_{abs} \cdot \rho_{subst}} \quad (1)$$

where:

$V_l$  – amount of flammable liquid ( $m^3$ );

$P_{atm}$  – atmospheric pressure ( $N/m^2$ ) = 94200  $N/m^2$ ;

$c_{subs}$  – concentration of flammable substance (% v/v) = 23 % diethyl ether;

$V_{cam}$  – test chamber volume ( $m^3$ ) =  $7,554 \cdot 10^{-3} m^3$ ;

$\mu_{subs}$  – molar mass of the flammable substance (g/mol) = 0,07412 kg/mol;

$R$  – universal constant of the ideal gas = 8,314 J/mol\*K;

$T_{abs}$  – absolute ambient temperature (K); for  $t_{amb} = 40^\circ C$  result  $T_{abs} = 313,15 K$ ;

$\rho_{subs}$  – density of flammable substance ( $kg/m^3$ ) = 713  $kg/m^3$ ;

The test sample used in the experimentation of test stand was the following limitation circuit:

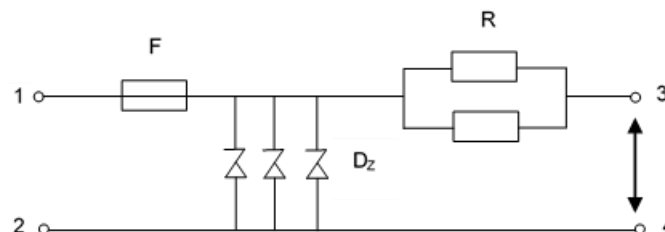


Fig. 4. Test sample used for the ignition test for small components

The electrical parameters of the circuit were:

$U = 6 V$ ;  $I = 586 mA$  between the terminals (1) and (2);

$D_z : 3 \times 5V6$ ;

$R : 2 \times 30 \Omega$ ; 0,5 W.

A short circuit fault between the terminals (3) and (4) was simulated during the test to obtain the highest temperature at the surface of the resistors.

*Step 2:*

- the test sample was placed in the test chamber (1) and the electrical connections with the power supply (6) were made;

*Step 3:*

- the thermocouples of type K/J have been placed on the small component surface under test (R) and inside the test chamber (1) for measuring ambient temperature;

*Step 4:*

- the multifunction module (9) has been connected to the small component (R) circuit for monitoring the electrical parameters during the test;

*Step 5:*

- the oxygen analyzer (3) has been checked / calibrated; the indication of the oxygen analyzer was calculated based on the diethyl ether concentration using the calculation formula from relation (2), obtaining the value of 15,89 % oxygen.

$$C_{required} = \frac{C_{oxygen\ before\ mixing} \% * (100 - C_{subs})}{100} \quad (2)$$

where:

$C_{oxygen\ before\ mixing}$  – the indication of the oxygen analyser before the introduction of the flammable substance (% v/v) = 20,64 %;

$C_{subs}$  – required concentration of the flammable substance (% v/v) = 23 % diethyl ether;

*Step 6:*

- after the test chamber was closed with a transparent plastic film, the heating process inside of the test chamber (1) was initiated until the temperature reached 40 ° C;

*Step 7:*

- the flammable test mixture was made in the test chamber (1) and the concentration of the explosive test mixture was confirmed with the oxygen analyser (3);

*Step 8:*

- the separation valves (14) was closed;

*Step 9:*

- after reaching the ambient temperature set inside the test chamber (1), the test sample having short-circuited terminals 3 and 4 was powered from the dual power supply (6) and the general thermal regime was monitored by the infrared thermal imaging chamber (13);

The test was carried out until it was noted that the temperature was decreased on the small monitored component (R resistance).

*Step 10:*

- considering the fact that during the test the explosive test mixture was not ignited by the heated surface of the small component monitored, the test sample was disconnected from the power supply and the explosive test mixture was ignited by the ignition initiating element (4).

## 5. Conclusions

The structure of the test stand and the performance of the component parts used enable that the ignition test for small components from the equipment intended for use in potentially explosive atmospheres to be successfully carried out.

An additional advantage of the test stand is that it allows the investigation of the thermal regime for small size components in order to determine the eligibility also for the type of protection encapsulation "m".

By using the transparent plastic film to close the test chamber, both the thermal regime visualization and the redundant indication of the ignition of the test mixture were facilitated.

## Acknowledgements

This article uses the experimental results obtained within Nucleu Program 2016, project PN 16 43 01 09 – “Stand for ignition test of small components from equipment intended for use in explosive atmospheres” and contributes to the achievement of the objectives within the Nucleu Program 2018, project PN 18 17 02 01 – “Researches for developing the assessment and testing of technical equipment designed for use in areas with hazard of explosion and of personal protective equipment”.

## References

- Andriș, A., Burian, C. S., Darie, M., Csaszar, T. A., Moldovan, I. L., Colda, C. I., Grecea, D. N., Botar, D., Aspects on selection of flammable substances for small components ignition test, *8th International Symposium on Occupational Health and Safety SESAM*, București, România, (2017).
- Burian, S., Ionescu, J., Ghicioi, E., Darie, M., Moldovan, L., Csaszar, T., Influence of environmental conditions on test mixtures used for testing of equipment with type of protection intrinsic safety, *Science and Technologies in Geology, Exploration and Mining - SGEM*, Albena, Bulgaria, Conference Proceedings, pp. 719-726, ISBN: 978-619-7105-07-0 ISSN: 1314-2704, (2014).
- Directive 2014/34/EU, *Directive of the European Parliament and of the Council on the harmonization of the laws of the Member States relating to equipment and protective systems intended for use in potentially explosive atmospheres*, (2014).
- IEC 60079-11, *Explosive atmospheres - Part 11: Equipment protection by intrinsic safety "i"*, On line at: <https://webstore.iec.ch/publication/626>, (2011).
- IEC 60079-0, *Explosive atmospheres - Part 0: Equipment – General requirements*, On line at: <https://webstore.iec.ch/publication/32878>, (2017).

# The limits of electrical grid for increasing the quality in three phases systems through the power flow control

Maria Daniela Stochitoiu<sup>a\*</sup>, Ilie Utu<sup>a</sup>

<sup>a</sup>University of Petrosani, Universitatii str.20, Petrosani 332057, Romania

## Abstract

Power systems components are loaded up to their limits and power trading with fast varying load patterns is leading to an increasing congestion. Taking into account the low possibilities to stock the electrical energy in alternative current systems it is necessary to balance the generated power and absorbed power. If the generated power is lower than absorbed power the frequency and the voltage are reducing, so the consumed power is decreasing for balancing the supplying power. If the voltage is maintained by the reactive power source than the load will be increase and the frequency will be keep to a low value and the power system will be crash; if there aren't a reactive power source a crack-up voltage will appear in the system.

**Keywords:** power factor; distortion effect; static Var compensator; capacity; inductance

## 1. Introduction

The only way to prevent the occurrence of voltage collapse is either to reduce the reactive power load or to provide the system with additional supply of reactive power before the system reaches the point of voltage collapse. This can be done by connecting sources of reactive power, i.e., shunt capacitors and/or Flexible AC Transmission System (FACTS) controllers at appropriate locations in the system. Flexible AC Transmission Systems (FACTS) technology helps utilities in reducing transmission congestion and in utilizing more efficiently the existing transmission system without compromising the reliability and security of the system. Their fast response offers high potential for power system stability enhancement apart from steady state flow control (Badea et al., 2013).

## 2. The concept of power flow control

It is considering an electrical line with the phase voltages at the ends:

$$\underline{U}_1 = U_1 \cdot e^{j\delta_1} \text{ and } \underline{U}_2 = U_2 \cdot e^{j\delta_2} \quad (1)$$

Using the ``long`` line equations (without losses  $g_0 \approx 0$ ,  $\eta_0 \approx 0$ ) it obtains active power transmitted by line between nodes 1 and 2 is directly proportional with the voltages  $U_1$  and  $U_2$  also difference between load angles  $\delta_1$  and  $\delta_2$  and inversely proportional to the resultant reactance (impedance) of the line  $X_{line}$  (Golovanov, 2009):

$$P_{12} = \frac{U_1 \cdot U_2}{X_{line}} \sin(\delta_1 - \delta_2) \quad (2)$$

$$X_{line} = Z_C \sin \varphi_{line} \quad (3)$$

$Z_C$  = the line characteristics impedance

$\varphi_{line} = \frac{2\pi L}{\lambda}$  the transmission angle corresponding to line (L-length)

$\lambda$  = the electromagnetically wave length

\* Corresponding author. Tel.: +40-726-278-241.  
E-mail address: danielastochitoiu@upet.ro

$$\begin{aligned}
 U_A &= U_B = U \\
 \delta_1 &= \delta, \delta_2 = 0 \Rightarrow \\
 P_{12} &= \frac{U^2}{X_{line}} \sin(\delta_1 - \delta_2)
 \end{aligned} \tag{4}$$

$P_n$  - the natural power

$$P_n = \frac{U^2}{Z_C} \Rightarrow P_{12} = P_n \frac{\sin \delta}{\sin \varphi_L} \tag{5}$$

From that equation is seen that is possible influence the power flow lines by change the resulting reactance (impedance) transmission path.

For increase the transferable active power using specifically compensate devices it can notice:

- the highest power is corresponding for  $\delta = \frac{\pi}{2}$  ;
- the highest power can be increase through decreasing the characteristic impedance and the transmission angle, separately or simultaneous.

Taking into account the distributed compensate concept [Kimbark], it follows the  $P_n$  natural power modify in dependence with transmits power, the involved parameters without compensate stage are:

$$Z_{C0} = \sqrt{\frac{X_{L0}}{B_{C0}}} ; \varphi_{L0} = \sqrt{X_{L0} \cdot B_{C0}} ; P_{n0} = U^2 \sqrt{\frac{B_{C0}}{X_{L0}}} \tag{6}$$

### 3. The control of transmits power through parallel compensation

$$B = B_{C0} - B_{der} = B_{C0}(1 - k_{der}) \tag{7}$$

Be  $k_{der} = \frac{B_{der}}{B_{C0}}$  the derivation degree ( $k_{der} > 0$  for inductive derivation and  $k_{der} < 0$  for capacitive derivation). The relations between parameters are:

$$Z_C = \frac{Z_{C0}}{\sqrt{1 - k_{der}}} \tag{8}$$

$$P_n = P_{n0} \sqrt{1 - k_{der}} \tag{9}$$

It can notice:

- using capacitors in parallel for derivate compensation, the characteristic impedance decreases but the transmission angle and natural power are increasing;
- through the inductive parallel compensation, the characteristic impedance is increasing but the transmission angle and natural power is decreasing.

### 4. The control of transmits power through serial compensation

The inductive reactance of transmission line is modified using serial compensation with capacitors. Be  $k_{serie} = \frac{X_{L0}}{\omega C_{serie}}$ , so  $X_L = X_{L0}(1 - k_{serie})$ , the relations between parameters without compensation and with compensation line are:

$$Z_C = Z_{C0} \sqrt{1 - k_{serie}} \tag{10}$$

$$P_n = \frac{P_{n0}}{\sqrt{1 - k_{serie}}} \tag{11}$$

It notices that increasing the serial compensation degree the characteristic impedance and transmission angle are decreasing but the natural power is increasing (Eremia, 2017).

### 5. How is influenced the load capacity of electrical line

Voltage stability is the ability of a power system to maintain voltages of power system buses after a disturbance in operating condition. On the other hand, voltage stability is the ability of power system to maintain or restore equilibrium point between demand and supply (Asuhaimi et al., 2016). Otherwise, instability results in progressive fall or rise of voltages in buses. Generally, loss of large loads, cascading outage of transmission lines and power system apparatus by protective schemes are pushing power system to voltage instability. Loss of generators synchronism event by outages or operating conditions is made to violate field current limitation. Hence, conventional methods for improving static stability are (Bindeshwar et al., 2011): Increasing the voltage; constructing new transmission lines; decreasing line series reactance by bundling; Installing series capacitors in transmission lines, decreasing transformers series reactance.

Total transmission capacity represents the highest power interchanged between two nodes without influencing of security power changes.

$TCC = \{\text{thermal limit, voltage limit, stability limit}\}$

If one of those limits is takeover the power system operating will be affect.

From insulation point of view the voltage level couldn't takeover some highest values. In operating a 10% of voltage increasing is acceptable. A lower voltage level increases the voltage stability and can determine the voltage crash-up phenomena. FACTS technology can be used for assure the conditions of overvoltage and power circulation.

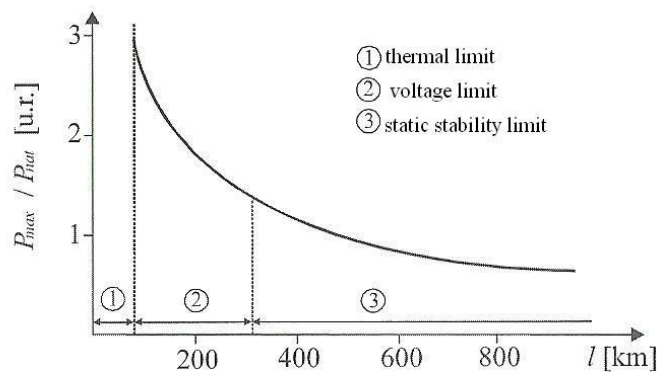


Fig.1. The highest heritable power for an electrical line

In the trans boundary power systems are a lot of electrical and magnetically interactions due to randomize customers and electric power plants behaviour which cause important oscillations of power, voltage and frequency (dynamic stability, static stability, voltage crash-up, synchronic resonance). Using the FACTS devices some stability limits can be annihilated.

The only way to prevent the occurrence of voltage collapse is either to reduce the reactive power load or to provide the system with additional supply of reactive power before the system reaches the point of voltage collapse. This can be done by connecting sources of reactive power, i.e., shunt capacitors and/or Flexible AC Transmission System (FACTS) controllers at appropriate locations in the system. Flexible AC Transmission Systems (FACTS) technology helps utilities in reducing transmission congestion and in utilizing more efficiently the existing transmission system without compromising the reliability and security of the system. Their fast response offers high potential for power system stability enhancement apart from steady state flow control (Badea et al., 2013). The benefits of employing FACTS are many: improvement of the dynamic and transient stability, voltage stability and security improvement, less active and reactive power loss, voltage and power profile improvement, power quality improvement, increasing power flow capability through the transmission line, voltage regulation and efficiency of power system operation improvement, steady state power flow improvement, voltage margin improvement, loss minimization, line capacity and load ability of the system improvement (Lascu, 2004).

A discussion of power system harmonics is incomplete without discussing the effects of power factor correction capacitors. In an industrial plant containing power factor correction capacitors, harmonic currents and voltages can be magnified considerably due to the interaction of the capacitors with the service transformer. This is referred to as harmonic resonance or parallel resonance. For a typical plant containing power factor correction capacitors, the resonant frequency (frequency at which amplification occurs) normally falls in the vicinity of the 5th to the 13th harmonic. Because nonlinear loads typically inject currents at the 5th, 7th, 11th, and 13th harmonics, a resonant or near-resonant condition will often result if drives and capacitors are installed on the same system (Stochitoiu et al., 2012).

In practice, power factor correction (PFC) techniques will influence both. There are two general forms of PFC, active (a-PFC) and passive (p-PFC).

As the name suggests, a-PFC utilises active electronic components to control the harmonic emissions. Due to the active control, the resulting input current waveform is very close to the ideal sinusoid, with a displacement power factor very close to unity and a very low THD<sub>I</sub>.

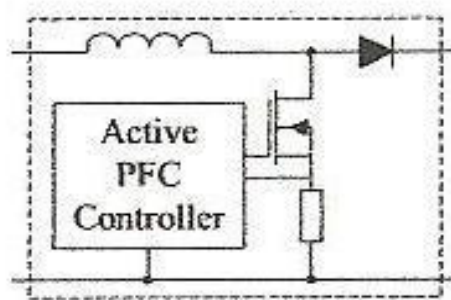


Fig.2. Active power filter correction



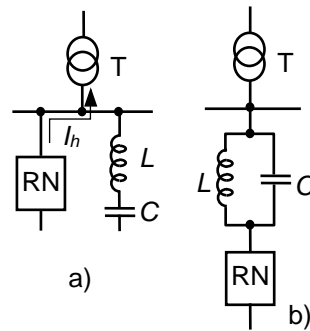


Fig.3. Passive Power Filter correction a) parallel b) serial

For stricter harmonic legislation, it may be necessary to include additional passive components in the circuit to satisfy harmonic limits. This is classified as passive-PFC (Golovanov, 2009). The most common p-PFC approach in the power electronics load category is to include an additional inductance in the conduction path to reduce the harmonic emissions. As inductors oppose the change of current, this will effectively reduce the rate of change of the current pulse and 'smooth' the input current waveform.

There are numerous benefits to be gained through power factor correction. These benefits range from reduced demand charges on your power system to increased load carrying capabilities in your existing circuits and overall reduced power system losses (Martínez et al., 2017). And the benefits of power factor correction aren't just limited to the balance sheet; there are also huge environmental benefits associated with power factor correction, which means your company is reducing its carbon footprint and helping the environment.

## References

- Abdullah A., s.a. *Comprehensive comparison of facts devices for enhancing static voltage stability* ARPN Journal of Engineering and Applied Sciences, ISSN 1819-6608, (2016).
- Badea A., s.a. *Surse regenerabile de energie*, Editura Agir, Bucuresti, (2013).
- Bindeshwar S., Verma K.S., s.a., *Introduction of FACTS controllers, a critical review*, International Journal of reviews in computing, Vol. 8, 31st December, (2011).
- Lascu D., *Tehnici si circuite de corectie activa a factorului de putere*, Editura de Vest, Timisoara, (2004).
- Golovanov C., *Masurarea marimilor electrice in sistemul electroenergetic*, Editura Academiei Romane, Bucuresti (2009).
- Eremia M., s.a. *Dispozitive FACTS, Concepte si aplicatii in electroenergetica*, Editura Agir, (2017).
- Martínez E.B, Camacho C.A. *Technical comparison of FACTS controllers in parallel connection* Journal of Applied Research and Technology 15, (2017).
- Stochitoiu M.D., Gruber A., *The modern estimation of power factor*, SIMPRO, Petrosani, (2012).

# Innovative and quality solutions with HVDC and FACTS – face to the new challenges

Maria Daniela Stochitoiu<sup>a\*</sup>, Marius Daniel Marcu<sup>a</sup>

<sup>a</sup>University of Petrosani, Petrosani Universitatii 20, 332006, Romania

## Abstract

HVDC and FACTS provide the necessary features to avoid technical problems in the power systems that increase transmission capacity and system stability very efficiently and they assist in prevention of cascading disturbances. They support the great access of renewable energy resources and reduce the transmission losses by optimization of power flows.

**Keywords:** renewable energy, static Var compensator, capacity, inductance

## 1. Introduction

Energy is a key factor for worldwide technology development, in providing a lifestyle and enhancing quality of life. An important energy production is based on fossil energy production.

Global demand for renewable energy is pushing renewable energy to the side of fossil fuel energy production. Fossil fuel has limited resources in the world and increasing production has increasing pollution problems. Central power stations are low efficient, high polluting stations which contribute to environmental issues. In order to overcome these problems structural changes are needed in power production to change non-renewable based production to renewable based energy production. Due to public interest, appears a pressure to develop technical solutions to increase amount of renewable energy in power production, and to use opportunities to utilize renewable energy resources and address the technical challenges.

Carbon dioxide concentrations are rising mostly because of the fossil fuels that people are burning for energy. Fossil fuels like coal and oil contain carbon that plants pulled out of the atmosphere through photosynthesis over the span of many millions of years; we are returning that carbon to the atmosphere in just a few hundred years.

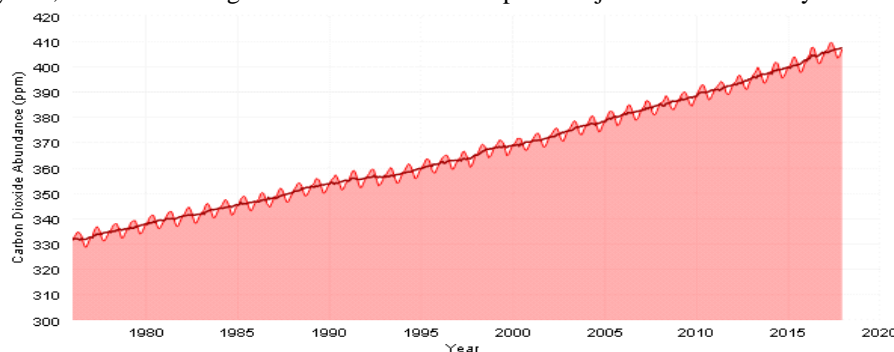


Fig.1 The evolution of CO abundance [www.climate.gov](http://www.climate.gov)

Worldwide interest towards renewable energy is a driving force to employ new technologies. Small-scale power production is replacing large-scale centralized power production. Intermittent energy as wind power and solar energy are causing negative effects to power quality, voltage, frequency and reliability. An increasing amount of intermittent energy increases problems for the grid.

\* Corresponding author. Tel.: +400254543382; fax: +400254543382.  
E-mail address: [danielastochitoiu@upet.ro](mailto:danielastochitoiu@upet.ro)

## 2. HVDC and FACTS converter technology

HVDC and FACTS controllers based on line commutated converter technology have a long and successful technology. Thyristor was the key components of this converter topology and have reached a high degree of maturity due to their robust technology and their high reliability. HVDC transmission technology offers new dimensions for long distance transmission. In general, for transmission distances above 700km, DC transmission is more economical than AC transmission at least 1GW.

HVDC and FACTS provide the necessary features to avoid technical problems in the power systems that increase transmission capacity and system stability very efficiently and they assist in prevention of cascading disturbances. They support the great access of renewable energy resources and reduce the transmission losses by optimization of power flows.

The power systems work with transmission alternative voltage lines 220kV, 400kV, 750kV and continuous voltage  $\pm 200\text{kV} \dots \pm 800\text{kV}$ .

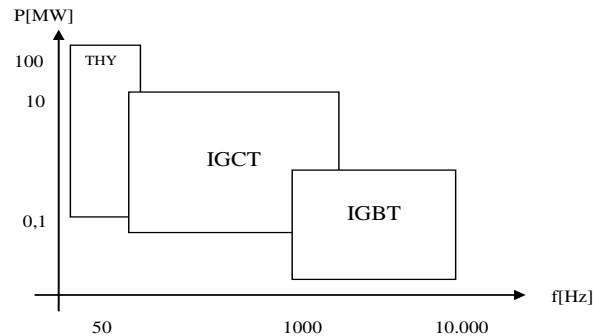


Fig. 2 Evolution of Si power electronics devices

Advances in power electronic technologies together with sophisticated electronic control methods made possible the development of fast static compensators namely Flexible AC Transmission Systems (FACTS). The FACTS technology has become one of the most valuable compensation techniques, because it applies the latest advances in power electronics to achieve additional and more effective control of the parameters of the electrical systems. This represents the most efficient combination of conventional primary equipment, high power semiconductor devices, microelectronics and telecommunications equipment, allowing a most flexible power electric system, (\*\*\*, 2012).

Table 1. The semiconductors characteristics for HVDC and FACTS

Types of semiconductors	Symbol	Characteristics				
		Highest turn-off voltage [kV]	Highest direct current [kA]	The commutation frequency [Hz]	The nominal power	$t_{off}$ [ $\mu\text{s}$ ]
Thyristor		8	5,5	50/60	kW-GW	50
Gate Turn Off Thyristor		4,5	4	<500	MW	10
Integrated Gate Commutated Thyristor		6,5	1,5	<1000	MW	5
Isolated Gate Bipolar Transistor		6,5	2,4	<1000	MW	2

Till today, the thyristor having the highest voltages and currents are used in almost all FACTS technologies and in some HVDC lines having  $\pm 800\text{kV}$  and power of 8GW. The thyristors are also using in static commutations from LCT (inductance controlled thyristor) and CCT (Capacity switched thyristor) in converters for static VAr compensator.

Especially in applications of wind plants off-shore the devices for HVDC must have small dimensions so, more devices can be integrated in the same semiconductors structure.

The main definition of FACTS is the A.C. Transmission System which incorporate static commutates based on power electronics which improve the controllability and increase the transmission capacity. Flexible AC Transmission Systems (FACTS) technology helps utilities in reducing transmission congestion and in utilizing more efficiently the existing transmission system without compromising the reliability and security of the system. Their fast response offers high potential for power system stability enhancement apart from steady state flow control, (Bindeshwar et al., 2011). The benefits of employing FACTS are many: improvement of the dynamic and transient stability, voltage stability and security improvement, less active and reactive power loss, voltage and power profile improvement, power quality improvement, increasing power flow capability through the transmission line, voltage regulation and efficiency of power system operation improvement, steady state power flow improvement, voltage margin improvement, loss minimization, line capacity and load ability of the system improvement, (Eremia et al., 2011).

The abbreviation for used FACTS devices are:

- TSSC – Thyristor Switched Series Capacitor
- SSSC – Static Synchronous Series Compensator
- TCVR- Thyristor Controlled Voltage Compensator
- CSC – Convertible Static Compensator
- SVC – Static VAr Compensator
- TCSC – Thyristor Controlled Series Capacitors
- STATCOM – Static Synchronous Compensator

In the last years, some mechanical switchers of parallel capacitors/inductances were being replaced by static switchers with thyristors. Nowadays the most used parallel devices are SVC and STATCOM. The modern devices of serial compensation are TSSC, TCSC and SSSC. The different FACTS devices contain as parallel components as well serial components connected together in the transmission system (as UPFC – Unified Power Flow Controller and IPFC – Interline Power Flow Controller), (Stochitioiu et al., 2018). These devices can control the important parameters of energy as line voltage, impedance, angle or active power flow and reactive power flow.

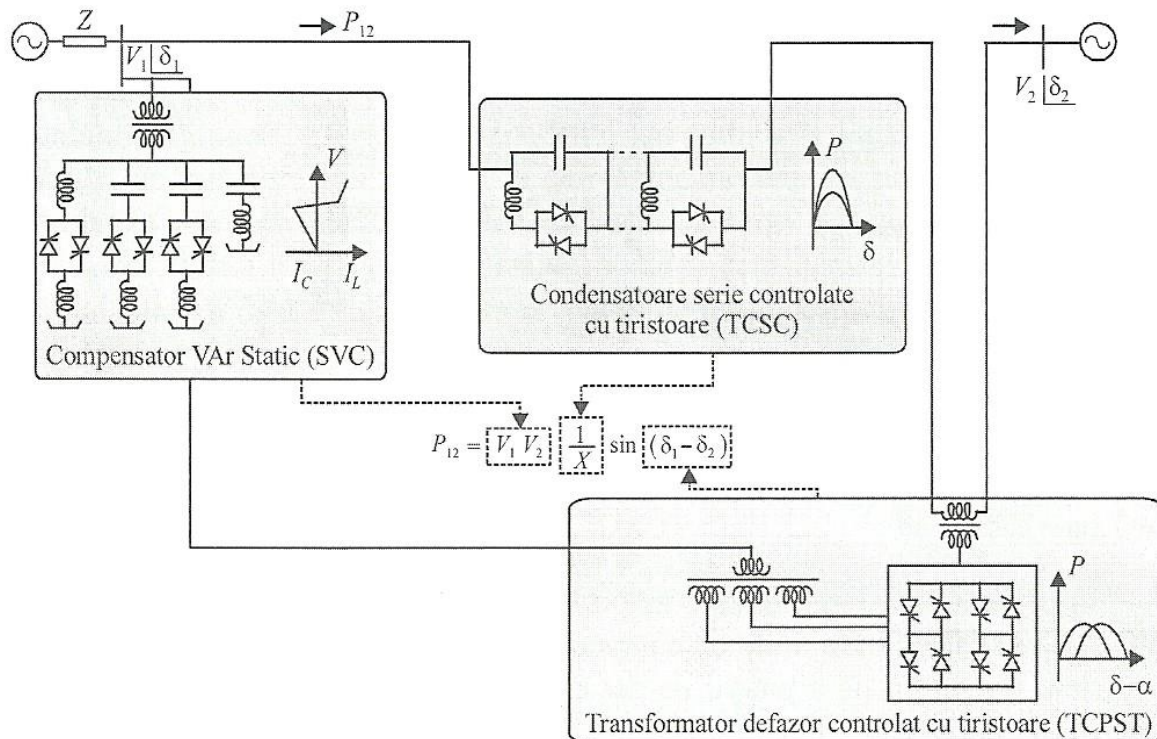


Fig.3 FACTS devices based on the conventional thyristors

In according with IEEE definition, Static VAr Compensator represents a reactive static power generator that is characterized by output parameters which can be modified by switching the inductive or capacitive current to control specific parameters of energetic system, especially the nodes voltage. Today the world faces a great challenge for providing energy, one of the most necessary resources, under the constraints to avoid the emission of pollutant substances and the rapid depletion of fossil fuel resources.

### **3. Conclusions**

Modern power systems are large, interconnected and involves thousands of buses and hundreds of generators. Power system protection devices also form a large part of the system. Environmental as well as economic factors primarily govern the installation of new power system and to transport this power, new transmission line construction are needed to meet the ever increasing load demand.

### **References**

- Badea Adrian, s.a. *Surse regenerabile de energie*, Editura Agir, Bucuresti, (2013).
- Bindeshwar Singh, K.S. Verma, s.a., *Introduction of FACTS controllers, a critical review*, International Journal of reviews in computing, Vol. 8, 31st December, (2011).
- Golovanov Carmen, *Masurarea marimilor electrice in sistemul electroenergetic*, Editura Academiei Romane, Bucuresti (2009).
- Eremia M., s.a. *Dispozitive FACTS, Concepte si aplicatii in electroenergetica*, Editura Agir, (2017).
- Martínez E.B., Camacho C.A. *Technical comparison of FACTS controllers in parallel connection* Journal of Applied Research and Technology 15, (2017).
- Stochitoiu M.D., s.a. *Modern concepts and its application for energetically security requirement at different connected sources*, SGEM Albena Bulgaria, june, (2018).
- IGBT Characteristics. Application Note AN-983*, International Rectifier-Infineon, (2012).

# Influence of power quality and efficiency for an energy delivery system real study case application

Mariana Dumitrescu<sup>a\*</sup>

<sup>a</sup>“Dunarea de Jos” University of Galati, 47 Domneasca Str., Galati, 800008, Romania

---

## Abstract

The paper presents an analysis of the efficiency and quality concerning a real case study for an electric delivery system. The purpose of the study is to find the potential negative effect of the unbalanced-non-linear loads on the delivery system. Giving the analysis results, a study about the possible techniques that will minimize this impact is done. Considering the real information from a supervisory-management system and using the professional designing/analysis software in the domain, the load duration curves are built for the HV/LV transformer stations. For the analyzed real study case delivery network, an algorithm and procedure of implementation of the methods improving efficiency and quality is accomplished. A solution for optimal sizing and location of the capacitors including harmonic filters is proposed, taking in consideration the optimal active and reactive power flow and also the rated bus tension levels to be maintained.

*Keywords:* Power systems; power delivery; power quality; power efficiency.

---

## 1. Introduction

Electrical networks reactive power flow and power factor compensation study uses the technical-economic optimizations for a Power Delivery-PD system case. From economically point of view reactive power sources can be installed if they decrease the active power losses in the network and the investment is justified. Specialist are taking in account to verify if the resulted reactive power compensation systems, proposed on economical-criteria, respect the voltage limits of normal conditions, which is only possible after the power flow computing (Bantras, 2012).

According with the PD theory, if compensation systems (reactive power sources-kvar) is implemented in the PD, financial savings are done, directly by reducing the billing rates and indirectly because of the smaller wires sizes (can still support the loads/the conductors cross-section is inversely proportional to power factor). On the contrary, when compensation of the PD is not done, it increases the power companies cost of power supplying and can cause overloaded generators/transformers/lines, reducing the load capability of the power systems in general (Masoudipour and Samed, 2013). Measurements are often taken to determine/reduce the level of harmonic pollution for the power system, due to unbalanced-non-linear loads. Harmonic measurements, done in a systematic way, are expensive/time consuming or error can appear due to the inaccuracies of measuring instruments or perhaps their wrong utilization. More and more the measurements are used mainly to validate power system modelling results, from the computer digital simulations.

## 2. Delivery System Study Case Efficiency

For the PD study case was done a simulation of the power flow for the initial operational stage, using the professional analysis and design software EDSA. The objective is to minimize the power losses for the analyzed PD system and also to minimize the total energy cost. This conduct to the maximization of the net annual cost saving, due to addition of the kvar compensation systems. The software was used for the power flow simulation and the power losses computation.

---

\* Corresponding author. Tel.: +0-074-703-8470; fax: +0-023-642-2672.  
E-mail address: mariana.dumitrescu@ugal.ro.

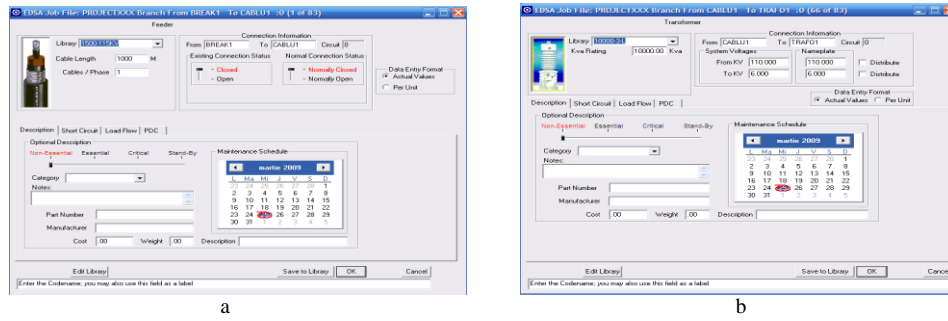


Fig.1. Data base to select the cables (a) and transformers (b) using the computer simulation

The introduced feeders input data are presented in Table 1 and the general system data are the following: kVCharge Cost=25.00(Euro/kVA/Year), kWh Energy Loss Cost=0.05(Euro/kWh), kvar Capacitor Investment Cost=2.00(E/kvar/Year. Fig. 1 presents the selection for the cables and transformers, with the help of the data base of the professional software, which are used in the analyzed industrial power delivery system network. In Fig. 2 is shown the single diagram for the analyzed power delivery system having radial feeders, designed in EDSA software. There are 6 transformation posts-PT, 6/0.4kV to insure the power supply for low power-LP consumers. The algorithm to find the optimal capacitors bank characteristics, in order to adapt the capacitor bank kvar at the load-reactive power curve, is conducting to a minimal reactive power supply from the system. Reactive power-load curves analysis has generally very large variations, showing kvar picks at evening and morning, but also kvar deeps during night and day.

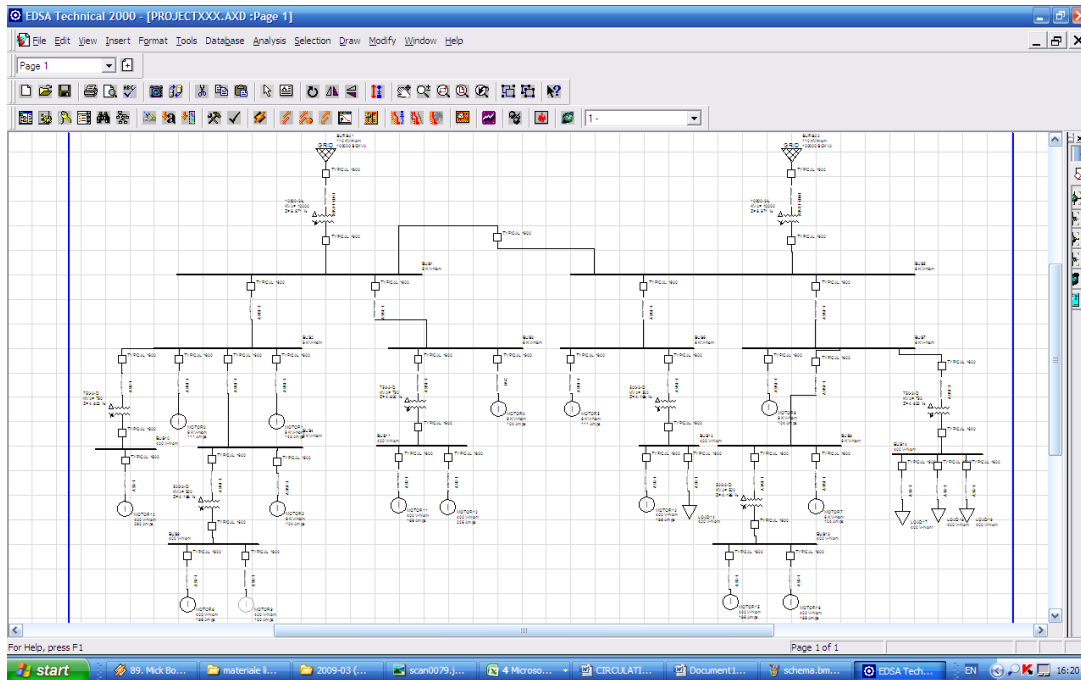


Fig.2. Power delivery study case-analyzed system

Table 1. Real study case single diagram feeders-input data

CABLE TYPE	LENGTH m	PH	POS SEQUENCE		ZERO SEQUENCE		VOLTAGE V
			RES %100MVA	RESC %100MVA	RES %100MVA	RESC %100MVA	
1	255	3	21.32	6.59	98.06	34.91	6.0000
2	1200	3	10.01	2.70	50.03	8.02	6.0000
3	1270	3	12.19	3.81	88.46	64.54	6.0000
4	550	3	14.99	4.21	67.54	75.30	6.0000
5	450	3	20.62	5.62	77.89	61.61	6.0000
6	480	3	12.47	3.73	58.15	66.31	6.0000
7	350	3	27.26	9.04	87.61	47.92	6.0000
8	400	3	13.44	3.33	62.84	54.77	400
9	160	3	10.58	4.04	48.66	3.43	400
10	350	3	29.26	9.04	12.61	47.92	400
11	150	3	24.13	6.04	68.58	56.21	400
12	300	3	12.96	3.67	45.61	19.43	400
13	396	3	33.14	10.24	342.43	54.26	400



### 3. Harmonic Regime Analysis

The capacitor function is correlated with the automations systems from the PD system and for optimal locating the capacitors we made measurement regarding the harmonic regime, with verification of the resonance with superior harmonics, because a possible failure of capacitor equipments can appear (Armonvipas and Hofmann, 2011), (Wangsong and Yonghai, 2013). For PD system, 6kV voltage, in the measure point-secondary of the electric transformer- 0.4kV, the parameters of harmonic regime need to be (IEEE Standard 519-1992): maximum total voltage distortions coefficient VTHD - 5%; maximum individual voltage distortion coefficient VTHD -3%; maximum total harmonic current distortion ATHD – 5% for  $I_{sc}/I$  value less then 20 and ATHD – 15% for  $I_{sc}/I$  value in 20- 1000 interval. Considering 519 IEEE Standard,  $I_{sc}$  value means maximum short circuit current at the measure point and  $I$  value means maximum demand load current at the measure point, computed to be the average of the maximum demand over the last 12 months.

Total harmonic current distortion quantifies the harmonic current distortion as a percentage of the maximum demand load current obtained in operating conditions lasting at least one hour. The level of voltage and current harmonics is standardized by CEI 1000-2-2/90 until the 40th harmonic. Fig. 3 and 4 show the results of the harmonic regime monitored by Qualistar-electrical power analyzer. They show a variable ATHD coefficient 11.5%-24.5% and a too big value for individual ATHD in case of L1 electrical circuit phase. For L1 electrical circuit phase case, ATHD distortion coefficient is bigger than its superior limit-15%, considering the interval of two monitoring hours (Cuk et al, 2013), (Mousavi, 2009).

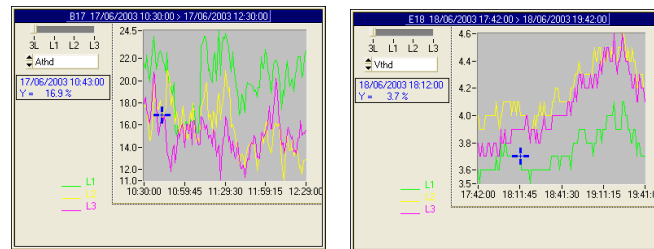


Fig. 3 ATHD and VTHD for L1, L2, L3 electrical circuit three phases for transformation post-PT 29

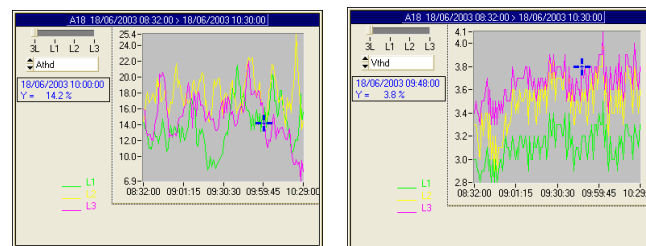


Fig. 4 ATHD and VTHD for L1, L2, L3 electrical circuit three phases for transformation post-PT 163.

The VTHD-coefficient, shown in Fig. 3, is over the superior limit 3%, considering the monitoring interval-two hours, but for L2 and L3 electrical circuit phases there are even bigger VTHD values than in L1-case. Fig. 4 shows ATHD and VTHD measure for L1, L2, L3 electrical circuit phases in PT 163-transformation post. The limits of individual ATHD values are 6.9% and 25.4%. The biggest value for individual ATHD is shown in the case of L2 electrical circuit phase. The individual VTHD coefficient is 2.8% - 4.1%, but L2 and L3 electrical circuit phases have VTHD values over 3% for the monitoring interval-two hours.

### 4. Power Delivery System Efficiency Improvement

Daily active and reactive power load curves were obtained using a measure data base for 6/0.4kV transformers secondary busbar, from the nominated transformer posts proposed for kvar compensation. Using the information were built daily active and reactive power load curves for the consumers. In Fig. 5-6 are shown the maximum values for active, reactive power flow for low voltage-LV network and also on for medium voltage-MV. Computation is made in seven consecutive days, considering the average values corresponding to five working days and two days of weekend, (Mousavi, 2009). We concluded that significant for the active and reactive power flow and efficiency improvement are the load curves for the working day, because for the weekend, power flow is low comparing with the working days.

Adding a capacitor on a radial distribution feeder means that it is capable to supply the customer reactive power and there will be no penalty for the company. The power company doesn't pay for reactive power delivered to consumers and also save a lot of the active power losses in feeders and transformers. For the analyzed power delivery system, have been proposed compensation capacitors system with harmonics filters to reduce the effect of harmonics and power losses (Hagh et al, 2011).

The computation is made for the hole day considering 15 minutes period, meaning 96 daily computations. It is necessary to use a capacitor banks solution, having power steps, so we elaborated an optimal algorithm of power steps computation. The optimal criteria is the efficient economical utilizations of the steps (not enveloped in the paper) and the results concerning the optimal solution are presented in the Table 2.

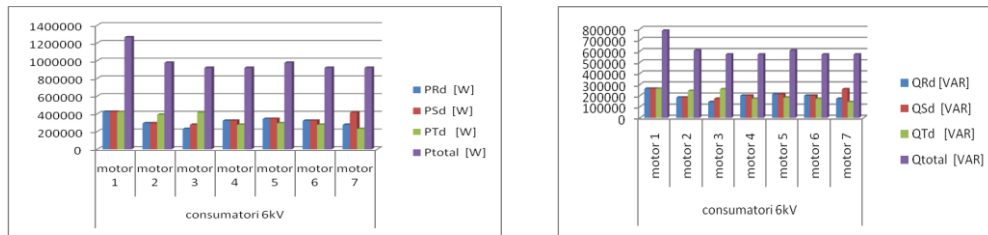


Fig.5. Active power flow, reactive power flow for MV network

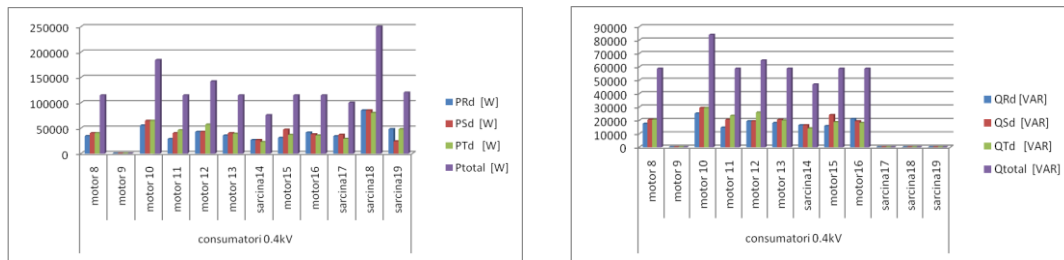


Fig.6. Active power flow, reactive power flow for LV network

Table 2. Simulation reactive compensation results

Nr. crt.	Min...Max reactive power for correction [kvar]	Reactive power steps [kvar]
BUS 2	278,66.....437,49	278,66/332,6/370,4/420,5
BUS 4	105,59.....189,99	105,59/137,7/156,1/185,33
BUS 3	97,73.....165,99	97,73/123,3/141,67/155,1
BUS 6	120,42.....191,24	120,42/159,43/183,24
BUS 7	125,56.....190,49	125,56/148,7/169,6/180,7
BUS 8	155,87.....229,99	155,87/189,23/216,43
BUS 10	10,76.....15,11	10,76/2,24/14,81
BUS 9	28,77.....58,21	28,77/37,45/56,21
BUS 11	9,45.....14,51	9,45/11,98/14,11
BUS 12	17,51.....24,31	17,51/20,52/23,61
BUS 13	13,35.....20,21	13,35/16,76/19,21

## 5. Conclusions

Today we must consider the technological developments and energy saving devices that have been developed in the last years. The new generation of electrical equipment has brought the need to include more and more the important task of the digital computer to make complex simulation of the regime. EDSA software is able to give adequate electric power system analysis, design and makes much easier the task for specialists in PD efficiency and quality improvement.

## References

- Amornvipas, C., Hofmann, L., Allocating harmonic emission limits at HV and EHV based on IEC61000-3-6 under consideration of global and future installations, *IEEE/PES Power Systems Conference and Exposition*, March, (2011).
- Bantras, T., Estimation and classification of power losses due to reduced power quality, *IEEE Transactions, Power and Energy Society*, Vol2, No 3, (2012).
- Cuk, V., Cobben, J.F.G., Kling, W.I., Ribeiro, P.F., Analysis of harmonic current summation based on field measurements, *The Institution of Engineering and Technology*, (2013).
- Masoudipour, I., Samet, H., Comparison of various reactive power definitions in non-sinusoidal networks with the practical data of electrical arc furnace, *IEEE Transaction on Electricity Distribution*, June, (2013).
- Mousavi, S., The review and analysis of destructive effects of harmonics on sample MV/LV transformer, *IEEE Transactions on Electricity Distribution*, pp. 1-4, (2009).
- Hagh, M.T, Milani, A.R., Azimzadeh M.R., Investigation of harmonic current source effects on distribution and transmission lines capacity and losses, *Technical and physical problems of engineering(IJTPE)*, September, (2011).
- Wangsong, H., Yonghai, X., Research on the switching method of bank of shunt capacitors in harmonic conditions, *International Conference on Mechatronic Sciences, Electric Engineering and Computer (MEC)*, December, (2013).

# Intelligent electrical micro network application with distributed energy resources

Mariana Dumitrescu<sup>a\*</sup>

<sup>a</sup>“Dunarea de Jos” University of Galati, 47 Domneasca Str., Galati, 800008, Romania

---

## Abstract

The operational benefits of the micro networks and also their environmental and economic benefits conduct in consequence to their acceptability and their possible degree of proliferation in the utility power industry, which are determined by the operational features. The automation, control, management and operational strategies for the micro networks can be very complex and also bring a significant conceptual difference, than the case of the networks used for the classical power systems. It depends of course on the type and penetration depth of the distributed energy resource units, supplying the micro network. The degree of dependence belongs to the load characteristics, power quality indicators and market participation strategies. This paper is presenting an overview of the importance and complexity of the micro network automation, control, strategies in the power and energy management. It describes their potential to the market participation and gives a practical sample.

**Keywords:** Power systems; electric distribution; micro networks; distributed energy resources; power quality.

---

## 1. Introduction

A micro network-MN is usually a part of the electric power distribution system that is located downstream of the distribution electrical substation. There are used, for the operational MN purpose, a wide variety of distributed energy resources-DER units which supply a wide variety of end consumers for electricity or combined heat-electricity. DER units are divided in two types: conventional or rotary units-interfaced to the micro network through rotating machines -, electronically coupled units - utilizing power electronic converters to provide coupling with the host system. The electrical connection point of the micro network to the utility system, at the low-voltage bus of substation transformers, constitutes the micro network point common coupling-PCC (Agarwal, et al, 2011), (Blaabjerg, et al, 2006). The MN serves a variety of residential buildings, commercial entities, and industrial parks. The MN can provide sufficient generation capacity, controls, and operational strategies to supply at least a portion of the load after being disconnected from the distribution system at the PCC and still remain operational in an autonomous way (Katiraei and Iravani, 2006).

## 2. Micro networks overview

In a conventional distributed generation unit-DGU the rotating machine is transforming the power of the energy resource into electrical power and is coupling, as an interface, the source with the MN. In an electronically coupled DGU case, the coupling converter can provide another layer of conversion and/or control, which acts to be an interface medium-MN. DER units include DGU and distributed storage-DS being usually connected at either medium- or low-voltage levels to the host MN. In Fig.1 is represented the block diagram for the DGU. The input power to the converter can be ac/dc fixed of variable frequency from the source side and it has a 50/60 Hz from the MN side of the converter. From power flow automation-control point of view, a DGU is dispatchable-DDGU or not dispatchable-NDDGU. A DDGU can become externally controlled using set points provided by a supervisory control system. The output power of a NDDGU is controlled based on the optimal operating condition of its primary energy resources. In Fig. 2 are represented the usual types for electronically interfaced DER units, a NDDGU photovoltaic (PV)-based DGU for which the PV array is interfaced to the host micro grid. From these three it can be highlighted the fact that a DGU with a non dispatchable power provider through a dc-ac/dc-dc/ac-dc converter can provide a dispatchable power at the output of the unit (Katiraei and Iravani, 2006), (Guerrero, 2013), (Katiraei et al, 2008).

---

\* Corresponding author. Tel.: +0-074-703-8470; fax: +0-023-642-2672.  
E-mail address: mariana.dumitrescu@ugal.ro.

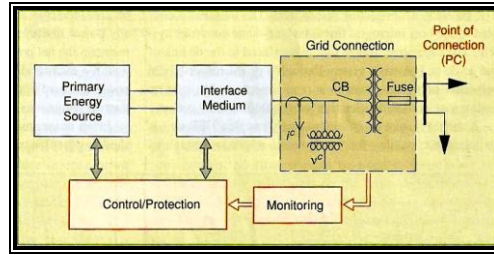


Fig. 1. Diagram of the block representation for a DGU

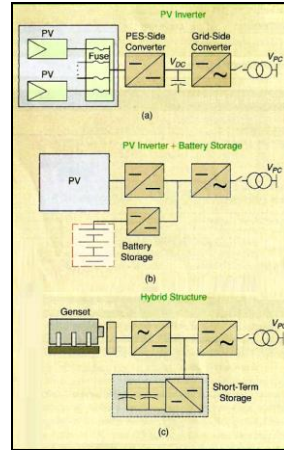


Fig. 2. Typical structures used for an electronically coupled DGU (a), NDDGU (b) and DDGU (c)

DER has dynamic response through its interface converter and the converter can provide also the limitation of the short circuit for the unit at 2 times the rated current. Due of the interface converter system there is a degree of electrical decoupling between the primary energy source and the distribution system limiting the dynamic interactions between the two subsystems, meaning the effects are less dangerous with the case of a conventional DGU (Llaria et al, 2011). In an autonomous operation it is necessary to maintain the power balance and consequently to stabilize the micro network voltage/angle. It means the operational strategy must take in account that the critical loads of the MN have priority. Furthermore, operation of a MN should accommodate functions such as customer service, power quality enhancement of specific load, reliability improvement of load categories. Load control can also be used to optimize the ratings of DS units and DDGU by reducing the peak load and by reducing the load excessive variations. DER can supply electrical and/or thermal consumers. In a conventional way the utility distribution system can be considered as supplying/absorbing any power discrepancy in the MN-generated power to maintain the net power balance. For loads, within a MN, is also an option if the imported/exported power has strong limits for operational strategies or contractual obligations. A part of a non-sensitive load can be considered a controllable and entered into a demand response control strategy, to either reduce the peak load and smooth out the load profile, or to schedule the load serving for specific time intervals when additional power, as from intermittent DGU is available. The non-controllable part of a non-sensitive load is the first candidate for load shedding. Load shedding and demand response are normally executed and supervised through the energy management controller of the MN.

DER units within a MN controls are selected based on the required functions and possible operational alternatives. Controls of a DER unit are also depending of the nature in interactions with the system and in other DER units. The main control parameters for a DER unit are voltage and frequency and / or active / reactive power control. The grid power export control strategy is often used to control the DER output power within the voltage and frequency. The control strategy can be implemented in the synchronous “dq0”, that specifies the direct (d-axis) and quadrature (q-axis) components of the converter, output currents corresponding to the real and reactive output power. Fig.3 shows a block diagram representation of a “dq0” frame controller (Lopes et al, 2006), (Olivares et al, 2011).

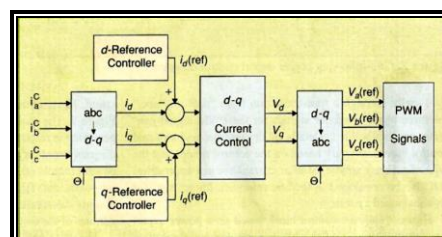


Fig. 3. The interfaced DER control block diagram

The control strategy emulates the behavior of a “swing source” in an autonomous MN. A grid within a MN can regulate the voltage at the PCC and to set mainly the system frequency. The DER should be large enough and have adequate reserve power capacity to supply the power balance. The power can be set by a supervisory power system-management system or it can be locally calculated according to a set power profile on purpose to optimize the active-reactive power export from the unit. In the case of more active DER units in MN frequency stability and voltage control, then frequency-droop and voltage-droop control strategies are used to share active-reactive power. This conducts to MN level of voltage and frequency which may deviate from the rated values, with respect to the acceptable limits, but depending on the load level and the droop characteristics. The controller inputs are the locally measured deviations in frequency and voltage for the unit. If DER units have different capacities, the slope of each droop characteristic is selected proportional to the rated capacity of the corresponding unit to prevent overloading.

Two DER units, working especially in an autonomous mode, require a power management strategy-PMS and an energy management strategy-EMS. Fast response of PMS/EMS for a MN is more critical compared with a conventional power system. Fig. 4 shows information/data flow and functions of a PMS/EMS for a MN, (Katiraei and Iravani, 2006), (Guerrero, 2013), (Katiraei et al, 2008).

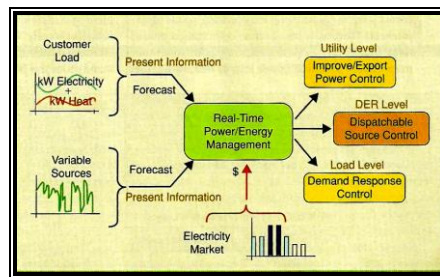


Fig. 4. PMS/EMS information flow and functions for a MN

The real-time power/energy/management block receives the present and the forecasted values of load, generation, and market information to impose appropriate controls on power flow, output generation, consumption level of the utility grid, dispatchable sources and controllable load, respectively. Through centralized control, can be optimized the MN-exchanged power with the host system, maximizing the local production which are depending on the market prices and security constraints. A nondispatchable control intends to provide the maximum autonomy for the DER units and load in a MN. The autonomy of the MNs implies that they are intelligent and can communicate with each other to form a larger intelligent system. In the nondispatchable control, the main task of each controller is not necessarily to improve the overall performance of the MN.

### 3. A Study Case

The MN in the proposed research topic is a real project implemented in the EB105 room located inside the Electrical Faculty UP Bucharest. The laboratory, having research and educational purpose, is equipped with adjustable DC voltage, 300V maximum voltage control (Fig. 5). These sources are: the main sources-SR photovoltaic type/ fuel cell type and DC stabilized source-SS fed from the classic network. The last can take over a part of electric charge when there is an important electrical load on the DC network, which exceeds the power produced by renewable sources. Provide energy storage battery is 240Ah.

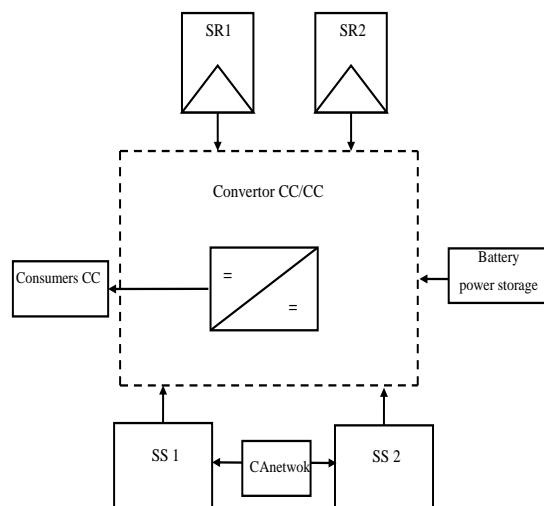


Fig. 5. MN case study structure



The available sources to provide electric power 230V DC, according with the laboratory need and its power consumers, have the following power ratings: SR1-1kW, SR2-1kW, SS1-920kW (230Vx4A), SS2-1380kW (230Vx6A). The electrical loads of the DC study case MN are intended for general lighting and required computing research activities (computers, monitors, lap-top). The loads are power supplied by the MN having two types of consumers: lamps, computers. The answer of the consumers, power supplied from the study case MN, will be tested in the two cases: DC smart grid, AC classical grid. For this analysis we used the following: the software- Labview programming environment; the hardware voltage transducers-current transducers-purchase card; USB/RS232 adapter; c.c. programmable sources, consumers (Fig. 6,7,8).



Fig. 6. Study case – research working bench

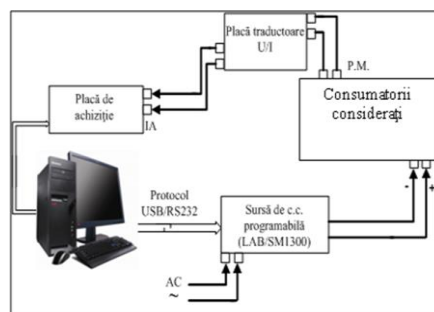


Fig. 7. Data analysis diagram

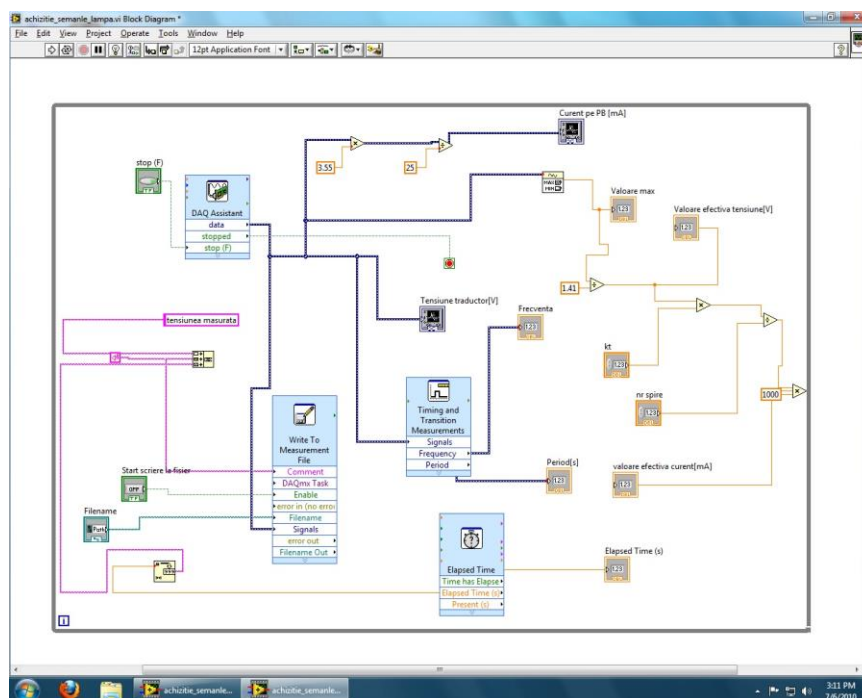


Fig. 8. Block diagram for MN-DC parameter control and computing

Two types of consumers were power supplied: fluorescent lamps and sources of computers in the both alternatives a) MN-DC, b) AC national power system. Both consumer types are switched to the different networks and power supplies. The proposed approach makes it possible to supply the consumers with the AC classical network or the smart DC-MN respectively. The effectiveness of tested components is the same in both alternatives, MN-DC or AC grid. The level of power supply voltage is ranged from a minimum of 40V, for the lamps and 100V for the computers, supplying till up to the rate voltage value. For an analyzed lamp, the diagram in Fig. 9 presents the differences of the current functions can be observed by variation of the voltage in the two cases a) or b), meaning MN-DC or AC grid.

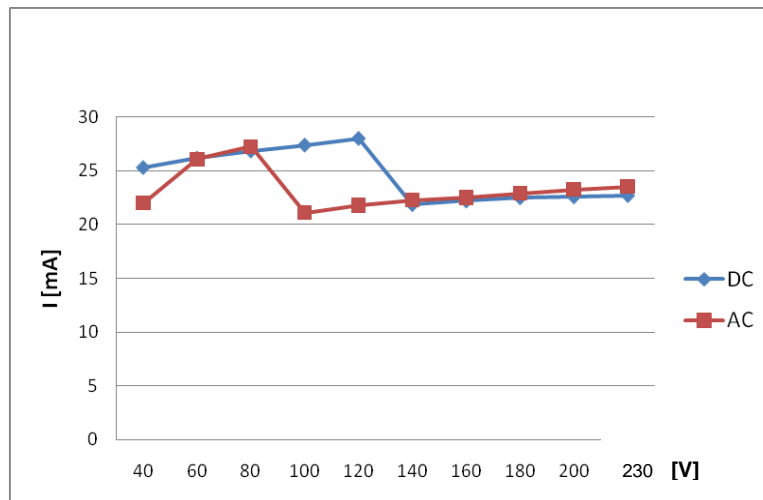


Fig. 9. Current variation in DC /AC for the tested lamp supplied by MN-DC/AC classical grid

For an analyzed computer, the diagram in Fig. 9 presents the differences of the current functions can be observed by variation of the voltage in the two cases a) or b), meaning MN-DC or AC grid.

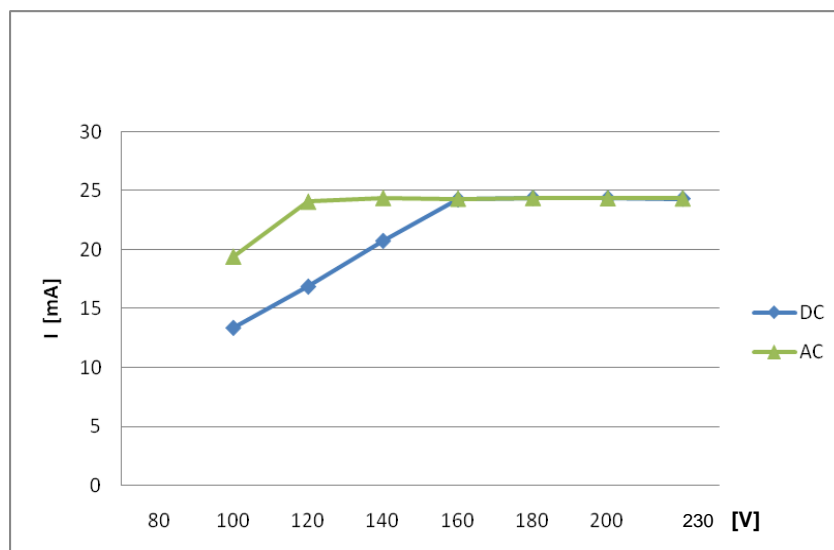


Fig. 10. Current variation in DC /AC for the tested computer supplied by MN-DC/AC classical grid

#### 4. Conclusions

This paper presented the most important differences between micro networks and classical power systems and advanced the research of using the micro networks in real study case application for a residential purpose. It clear up the development of control and operational strategies for micro networks, which were seen as miniaturized versions of the conventional power systems, and intuitively their control/operational concepts were based on scaled-down and simplified versions of control-operational-management strategies concepts of the classical power systems. Market availability for the DER units technologies and the gradual and consistent increase in their way to penetrate the power



systems, have generated significant interest in integration, controls, and optimal operation DER units in the context of micro networks. The real study case, presented in the paper, implemented the proposed DC micro network and safely supplied the consumers, which were tested and efficiently adapted to MN-DC- power supply.

## References

- Agarwal, Y., Weng, T., Gupta, R. K., Understanding the role of buildings in a smart microgrid, *Proceedings of the 14th Design, Automation and Test in Europe Conference and Exhibition (DATE '11)* March, pp. 34-41, (2011).
- Blaabjerg, F., Teodorescu, R., Liserre, M., Timbus, A.V., Overview of control and grid synchronization for distributed power generation systems”, *IEEE Trans. Ind. Electron.*, Vol. 53, No. 5, pp. 1398-1409, October, (2006).
- Dimeas, A.L., Hatziargyriou, N.D., Operation of a multiagent system for microgrid control”, *IEEE Trans. Power Syst.*, Vol. 20, No. 3, pp. 1447-1457, August, (2005).
- Guerrero, J. M., Chandorkar, M., Lee, T., Loh, P. C., Advanced control architectures for intelligent microgrids, part I: decentralized and hierarchical control, *IEEE Transactions on Industrial Electronics*, pp. 76-85, (2013).
- Katiraei, F., Iravani, R., Power management strategies for a microgrid with multiple distributed generation units, *IEEE Trans. Power Syst.*, Vol. 21, No. 4, pp. 1821-1831, November (2006).
- Katiraei, F., Iravani, R., Hatziargyriou, N., Microgrids Management, *IEEE Power and Energy*, Vol. 6, No. 3, pp. 54-65, June (2008).
- Llaria, A., Curea, O., Jiménez, J., Camblong, H., Survey on microgrids: unplanned islanding and related inverter control techniques, *Renewable Energy, Elsevier*, Volume 36, Issue 8, pp. 2052-2061 (2011).
- Lopes, J.A.P., Moreira, C.L., Madureira, A.G., Defining control strategies for microgrids islanded operation, *IEEE Trans. Power Syst.*, Vol. 21, No. 2, pp. 916-924, March (2006).
- Olivares, D. E., Cañizares, C. A., Kazerani, M., A centralized optimal energy management system for microgrids, *Proceedings of the 2011 IEEE Power and Energy Society General Meeting*, July (2011).

## Study of the electromagnetic compatibility parameters of LED lighting sources

Krasimir Marinov Ivanov<sup>a</sup>, Tsviatko Kolev Varbov<sup>a</sup>, Georgi Tsonev Velevev<sup>a\*</sup>,  
Panayot Ivanov Yankov<sup>a</sup>

<sup>a</sup>Technical University of Gabrovo, 5300 Gabrovo, Bulgaria

---

### Abstract

The paper inhere presents results of measurements in regard with current harmonics, injected in the electrical power system by various LED lighting sources. Measured values have been analyzed according to the international standard IEC 61000 (Electromagnetic compatibility (EMC) - Part 3-2: Limits for harmonic current emissions (equipment with input currents up to 16 A per phase). A relation has been found between the intensity of current harmonics and the luminous flux flicker.

*Keywords:* Electromagnetic compatibility (EMC); LED; current harmonics; luminous flux; flux pulsation.

---

### 1. Introduction

In the recent years, energy efficient compact fluorescent lamps (CFLs) and LED lamps are widely used as electrical lighting sources. Along with that, their power supplying units generate significant harmonic current, which are flowing back into the electricity supplying power network, causing excessive active power losses and other negative effects. Nowadays, the mass use of such lighting sources in households, public and industrial buildings and outdoors could lead to a deterioration of the electrical energy quality, supplied to consumers and to problems in their operation. The most common issues of electrical equipment, related to high levels of harmonics in the electricity supply are: excessive heat in the ferromagnetic cores of power transformers and electrical rotating machinery; over currents in capacitors as a result of the decrease of their impedance for the higher harmonics, present in the mains (Istalianov and Voivodov, 2014), (Jettanasen and Pothisarn, 2014), (Uddin et al., 2012).

In Europe, the main legal document regulating the emission limits of harmonic currents (for devices and equipment with input currents up to and including 16 A per phase) is EN 61000-3-2: 2014 (IEC 61000-3-2: 2014).

The objective of the paper below is to investigate the harmonic "pollution" in electrical power supplying installations for lighting, caused by the use of LED lamps.

### 2. Legal requirements for harmonic emissions limits and measurement setup

According to the standard EN 61000-3-2: 2014 electricity operated appliances and equipment are divided into 4 classes:

- class A - symmetrical three-phase electrical equipment, domestic appliances, non-portable electric tools, audio equipment, etc.;
- class B - includes hand-held portable electric tools and equipment not referring to professional and arc welding.
- class C - comprises lighting devices (luminaires).
- class D - electrical appliances and equipment with rated power less than 600 W (PCs, monitors, TVs, etc.)

Harmonic emission limits for electrical equipment class C are divided into two groups – for equipment with power rating up to 25 W and over 25 W.

---

\* Corresponding author. Tel.: +359-899-821-208  
E-mail address: g.velev@gmail.com

Having in mind electrical installations, supplying lighting sources with rated power above 25 W, the following harmonic emissions limits are shown in Table 1.

Table 1. Harmonics emissions limits for equipment class C, with rated power over 25 W

Harmonic order	Maximum permissible harmonic current expressed as a percentage of the input current at the fundamental frequency, %
2	2
3	$30 * \lambda$
5	10
7	7
9	5
$11 \leq n \leq 39$ (Only odd)	3
	2
$\lambda$ – power factor	

The performed study for measuring the harmonic “pollution” in an electrical system supplying lighting sources comprises lamps and luminaires, produced by leading companies on the Bulgarian market. There have been tested lamps with different color temperatures and power ratings more than 25W. Intentionally the names of the producing companies are not specified. The technical specifications of the lamps that have been tested are provided in Table 2.

The following measuring instruments have been used in regard with the electrical parameters needed for the study: electrical power network analyzer HT GSC53N and a digital oscilloscope Hantek DSO5102P. Each light source has been studied independently.

Table 2. Technical specifications of LED luminaires that have been tested

№ of lamp	Rated Power, W	Technical specifications
1	30	LED floodlight, 220V
2	30	LED floodlight 6000K, 2600lm, 120°, 85V ÷ 265V
3	30	LED floodlight 6400K, 2500lm, 120°, -20 °C ÷ + 40 °C, 90V ÷ 260V
4	50	LED floodlight 6000K, 4300lm, 120°, 85V ÷ 265V
5	50	LED floodlight 6400K, 4000lm, 120°, -20 °C ÷ + 40 °C, 220V ÷ 240V
6	50	LED floodlight 6000K, 5000lm, 120°, -30 °C ÷ + 45° C, 220V ÷ 240V
7	30	LED floodlight 6000K, 3000lm, 120°, -30 °C ÷ + 45 ° C, 220V ÷ 240V
8	30	LED floodlight 6000K, 2700lm, 120°, -30 °C ÷ + 45 ° C, 100V ÷ 240V
9	50	LED lamp Ø160mm, flat,
10	32	LED lamp Ø190mm, flat,
11	40	LED lamp, globe

### 3. Measurement results and interpretation

Summarized data from the preformed measurements is presented in Table 3 and Table 4. Table 3 comprises results for lighting sources with numbers from 1 to 11 in regard with their harmonic currents, in absolute values and respectively as a percentage of the fundamental harmonic.

The total harmonic distortion of the current curve THDi, % in Table 3 has been calculated by expression (1).

$$THDi = \frac{\sqrt{I_2^2 + I_3^2 + I_4^2 + I_5^2 + \dots}}{I_1} \cdot 100, \% \quad (1)$$

, where  $I_i$  is the current of the  $i$ -th harmonic.

Luminous flux pulsation (flicker) can be calculated according to expression (2). It is the ratio of the difference and the sum of the maximum and minimum values of the luminous flux (Petrov and Varbov, 2007).

$$Flic = \frac{\Phi_{MAX} - \Phi_{MIN}}{\Phi_{MAX} + \Phi_{MIN}} \quad (2)$$

Table 3. Measurement results for lighting sources 1-11

Study of LED Lamps												
	№ of lamp	№1	№2	№3	№4	№5	№6	№7	№8	№9	№10	№11
Voltage, V		225.9	225.8	225.8	229.5	225.5	225.4	225.2	225.2	242.8	242.8	242.8
Current, mA		129.8	138.7	139.9	222.2	223.1	224.3	135.8	215.9	213	188.3	223.2
Active power, W		29	31	29.4	50.4	48.6	50.8	30.7	30.7	50.7	30.13	35.1
$\cos \varphi$		1	0.99	0.93	0.99	0.97	1	1	0.63	0.98	0.95	0.65
THDi, %		<b>16.2</b>	<b>11.5</b>	<b>18</b>	<b>12.1</b>	<b>11.2</b>	<b>9.5</b>	<b>9.5</b>	<b>100</b>	<b>21.5</b>	<b>100</b>	<b>100</b>
Harm. order												
Harmonic current, mA	1	125.8	133.7	137.6	220.4	221.8	223.3	135.6	137.5	204.5	134.8	148.9
	3	10.6	8.1	17.6	12.5	13.9	17.8	10.8	119.6	26.1	108.7	123.4
	5	13.5	12.1	13.9	17	16.9	10.6	6.7	85.3	27.1	67.3	83.1
	7	10.6	6.1	9.7	13.9	10.6	3	1.9	56.5	19.6	35.8	47.8
	9	-	1.4	3.6	5.1	4.7	4.3	2.3	33.7	7.9	21.7	27.7
	11	3.3	-	2.3	-	-	-	-	20.6	-	11.9	16.3
	13	2.3	-	-	-	-	-	-	14.1	4.1	7.6	10.8
	15	-	-	1.9	-	-	-	-	11.9	4.6	-	-
harm. order												
Harmonic current, %	1	100	100	100	100	100	100	100	100	100	100	100
	3	8.3	5.8	12.7	5.7	6.3	8	8	86.5	13.2	81.3	83.5
	5	10.5	8.8	10.1	7.7	7.5	4.5	4.9	62.3	13.2	51.2	55.6
	7	8.2	4.4	7.1	6.3	4.8	1.5	1.4	41.8	9.8	27.3	33
	9	-	2	2.6	2.3	2.0	1.9	1.7	24.7	3.7	17.3	19.1
	11	2.6	-	1.7	-	-	-	-	15.1	-	9.9	11
	13	1.8	-	-	-	-	-	-	10.3	2	5.8	7.5
	15	-	-	1.4	-	-	-	-	8.3	2.7	-	-

Figures 1 and 2 illustrate the curves of current variation against time flowing through the LED lamp (in yellow) and the luminous flux emitted by the lamp (in blue color). The offset of the luminous flux curve in the time domain relative to the “x” axis allows determination of the luminous flux pulsation coefficient (flicker).

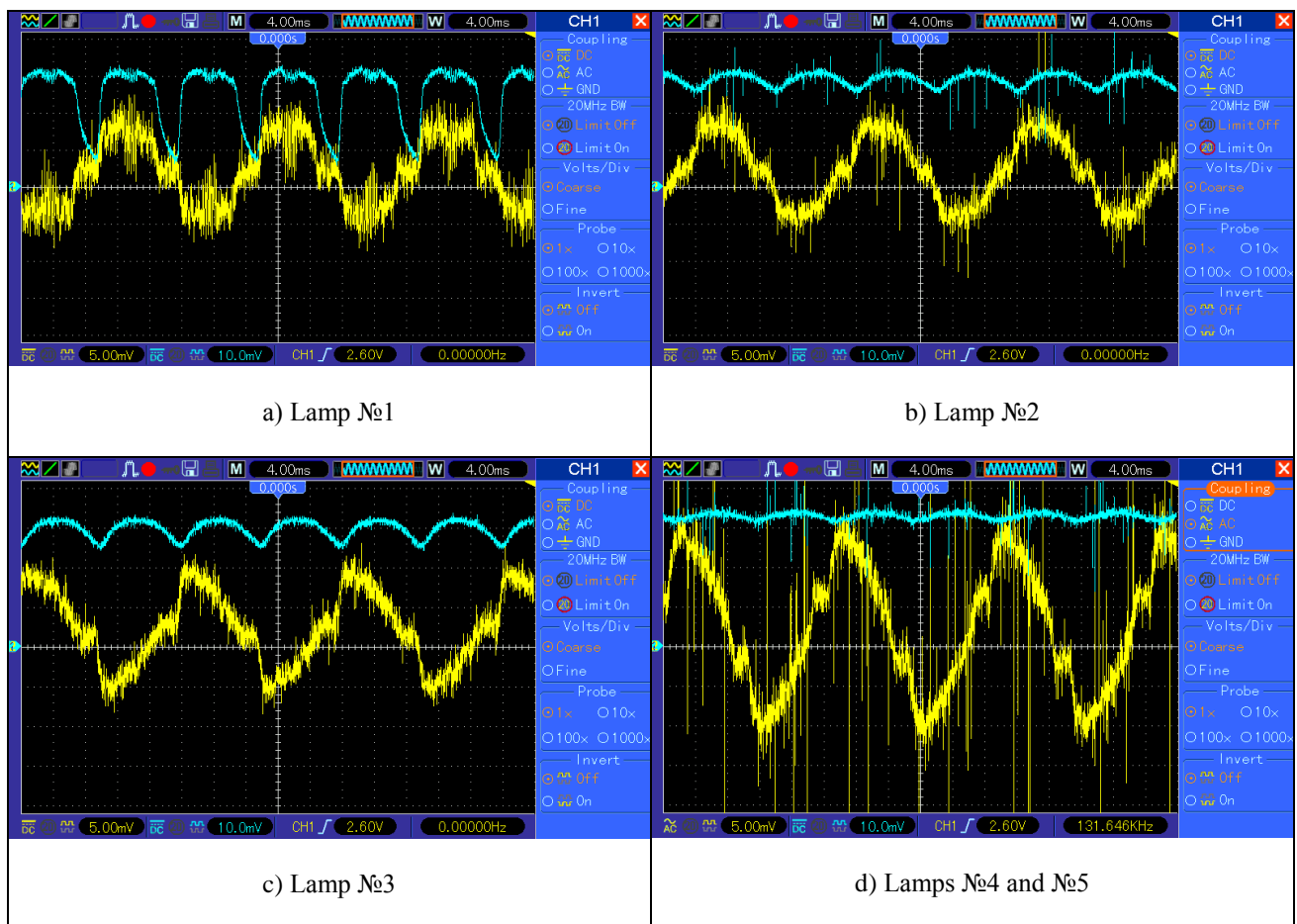


Fig. 1. Time diagrams for the operation of LED lamp №1(a), №2(b), №3(c), №4 and №5 (d)

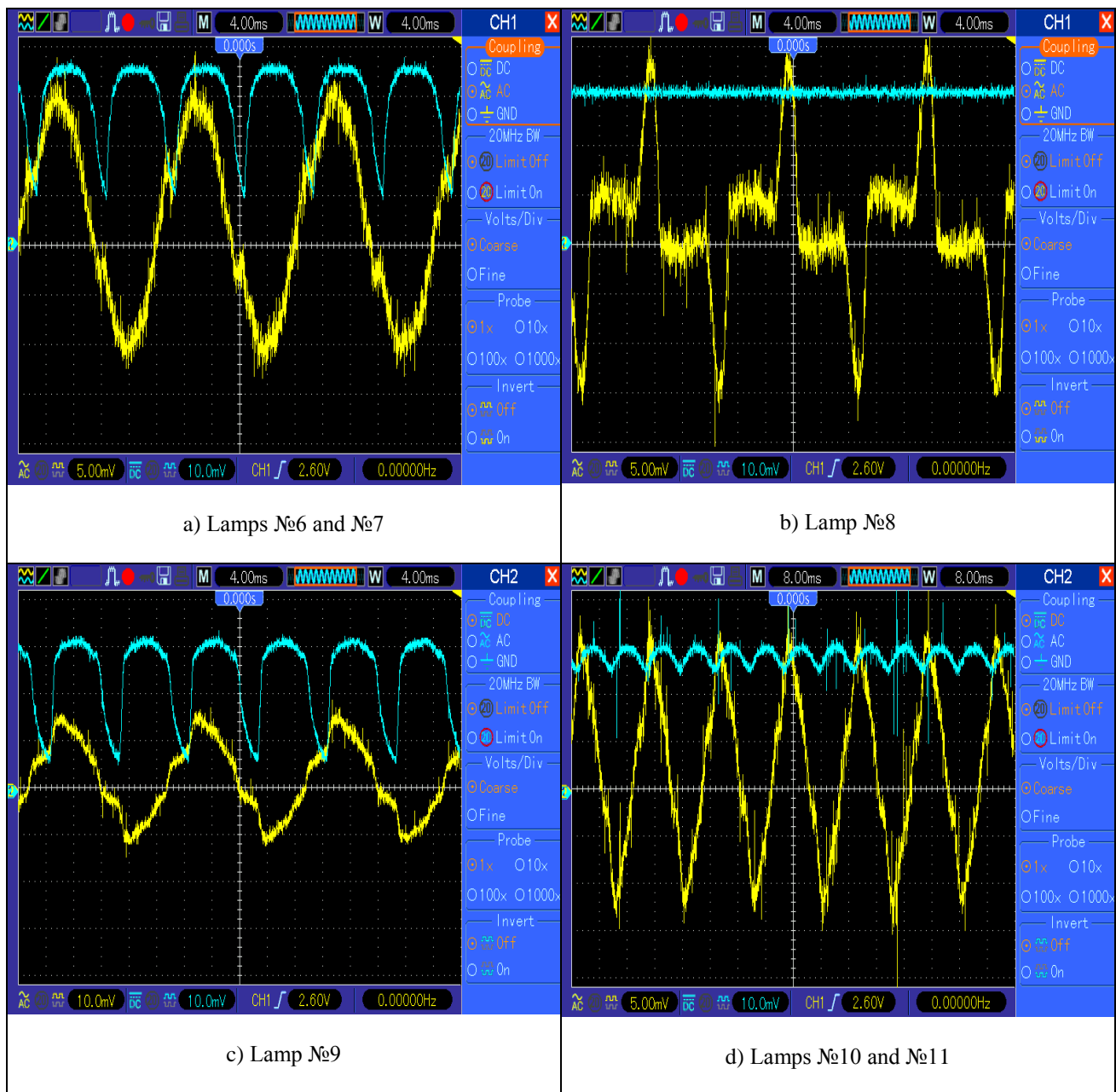


Fig. 2. Time diagrams, observed under the operation of LED lamp №6(a), №7 and №8 (b), №9(c), №10 and №11(d)

LED lamps №4 and №5 and №10 and №11 have similar variations of the flowing current and the luminous flux with time.

Observing the results for LED lamps №2, №3, №4, №5, №6, №7 and №9 it can be concluded that they meet the limit requirements for emission of odd harmonic currents and total harmonic distortion in the current curve according to standard EN 61000-3-2: 2014 (IEC 61000-3-2: 2014).

LED lamp №1 has harmonic current and THDi values slightly exceeding the limit values.

LED lamps №8, №10 and №11 are exceeding the emission limits for harmonic current components in accordance to standard EN 61000-3-2: 2014 (IEC 61000-3-2: 2014). Lamp №8, which exceeds the emission limit values for odd harmonic currents and THDi doesn't have pulsation of the luminous flux. Lamps №10 and №11 are also exceeding the emission limits for odd harmonic currents and THDi, but compared to №8 has noticeable luminous flux pulsations.

LED lamps №1, №6, №7 and №9 do not exceed emission limits of harmonic currents, but they have significant luminous flux pulsations.

LED lamps №2, №3, №4, №5 and №6 also do not exceed emission limits of harmonic currents, but they have very slight luminous flux pulsations.

### 3.1. Influence of operating voltage over the emission of harmonic currents

The following Table 4 comprises results associated with the influence of the operating voltage over the emission of harmonic currents tested for LED lamps №2, №3 and №4. Operation voltage under test has been regulated in accordance with the requirements for voltage deviation in the range  $U_N \pm 10\%$  for public power distribution networks as regulated in the standard EN50160: 2010 (Tsanev and Tsvetkova, 2011).

After the test it has been generalized that operating voltage doesn't affect significantly harmonic currents emission. For the tested LED lamps' samples there is now exceeding of the harmonic emission limits.

In general, we have found an important correlation between luminous flux pulsations and the increased emission of harmonic currents for LED lamps №8, №10 and №11. At the same time the intensive luminous flux pulsations of LED lamps №1, №6, №7 and №9 are not associated with exceeding the emission limits of harmonic currents.

LED lamps №8, №11 and 10 have high levels of harmonic currents emission and increased THDi rates.

Table 4. Influence of operating voltage upon harmonic currents emission

LED lamp data		№2 30W LED			№3 30W LED			№3 50W LED		
Voltage, V		207	230	253	207	230	253	207	230	253
Current, mA		146.8	133.1	121.3	145.5	134.9	128.5	244.3	220	199.7
Active power, W		30	29.7	29.7	28	28	28	50.1	49.8	49.5
$\cos \varphi$		0.99	0.98	0.97	0.93	0.9	0.88	0.99	0.99	0.98
<b>THDi, %</b>		<b>10.8</b>	<b>11</b>	<b>11.2</b>	<b>15.8</b>	<b>17.3</b>	<b>18.6</b>	<b>12.2</b>	<b>12.3</b>	<b>12.4</b>
Harmonic current, mA	Harm. order									
	1	145.8	130.3	120.1	132.6	128.7	143.4	242.1	217.9	197.8
	3	7.1	7.2	8.1	17.6	18.4	16.3	11.5	12	14.3
	5	12.2	10.7	9.6	12.2	11.8	12.8	21.6	17	13.9
	7	6.4	5.5	4.7	7.9	7.8	8.6	14.5	13.1	12
	9	1.9	1.4	1.4	3.3	3.6	3	5.5	6	5.7
	11	-	-	-	1.4	1.4	-	-	-	1.9
	13	-	-	-	-	-	-	-	-	-
	15	-	-	-	-	-	-	-	-	-

## 4. Conclusions

Based on the performed study for harmonic current “pollution” in low-voltage electrical power installations, supplying LED lamps with rated power more than 25W, the following conclusions are made:

- 50% of the LED lamps with respect to the intensity of harmonic currents that they emit, have high levels of luminous flux pulsations;
- Power factor of the tested LED lamps is generally higher than 0.9 with the exception of two lamps that have values to about 0.65.
- Reduction of luminous flux pulsations in 3 of the LED lamps (27%) is related with exceeding the admissible limit values of harmonic currents and THDi;
- Reduction of luminous flux pulsations improves the lighting quality and eliminates the possibly for occurrence of stroboscopic effect, which is important technical indicator in occupational safety.
- The comparatively small share of LED lamps and luminaires with their installed power rating, compared to the other high power loads attached to the electricity system, doesn't cause increase in the total harmonic distortion of the voltage curve ( $THD_U$ ).

## Acknowledgements

All experiments have been performed in the laboratories of the Technical University of Gabrovo at the department “Basic Principles of Electrical and Power Engineering”. The used LED lamp samples are from leading manufacturers in the country and worldwide. Authors would like to thank sincerely to the producers, retailers and representatives of the LED lamps that have been kindly provided them for this study.

## References

- Istalianov R., Voivodov, V., *Research of harmonics in led lighting*, Bulgarian XV National Conference Lighting BullLight 2014, Bulgaria, Sozopol, (2014).
- Jettanasen C., Pothisarn, C., *Analytical Study of Harmonics Issued from LED Lamp Driver*, International Multi-Conference of Engineers and Computer Scientists (IMECS), Vol II, Hong Kong, March 12 – 14, (2014).
- Petrov P. K., Varbov, Ts., *Experimental determination of the luminous flux pulsation coefficient*, Occupational Safety and Medicine, Vol. 5, ISSN 1311-2740, (2007).
- Tsanev Ts., Tsvetkova, Sv., *Power Quality*, Publishing House "Avangard Prima", Sofia, ISSN 978-954-323, (2011).
- Uddin S., Shareef, H., Mohamed, A., Hannan, M. A., *An analysis of harmonics from LED lamps*, Asia-Pacific Symposium on Electromagnetic Compatibility, 21-24 May, (2012).
- EN 61000-3-2:2014, *Electromagnetic compatibility (EMC). Limits. Limits for harmonic current emissions (equipment input current  $\leq 16$  A per phase)*, (2014).
- EN 50160:2010, *Voltage characteristics of electricity supplied by public electricity networks*, (2010).



## A quality-based approach for improving the lighting design process

Dragos Pasculescu<sup>a\*</sup>, Leon Pana<sup>a</sup>, Georgeta Buica<sup>b</sup>, Vlad Mihai Pasculescu<sup>c</sup>, Remus Dobra<sup>d</sup>

<sup>a</sup>University of Petrosani, 20 Universitatii street, Petrosani, Romania

<sup>b</sup>National Institute for Research and Development in Occupational Safety “Alexandru Darabont”, 35 A Ghencea Boulevard, Sector 6, Bucharest, 061692, Romania

<sup>c</sup>National Institute for Research and Development in Mine Safety and Protection to Explosion – INSEMEX, 32-34 G-ral Vasile Milea Street, Petrosani, 332047, Romania

<sup>d</sup>“1 Decembrie 1918” University of Alba Iulia, 5 Gabriel Bethlen Street, Alba Iulia, 510009, Romania

---

### Abstract

The current paper provides an analysis on the lighting within a production hall, case in which the visual comfort of workers has to be ensured by inducing them positive sensations during their activity, such as visual performance, which determines the fast and clear perception of the visual load, even in difficult conditions and for long periods, so that the workers to be able to visually perceive the surrounding environment. Therefore, there is carried out a comparative study on the general lighting of a production hall, between the case of fluorescent lamps and the case of LED technology. Following the performed study, there is revealed the necessity of using quality lighting for the development of production processes in best conditions, as well as for an as low as possible power consumption.

**Keywords:** lighting quality; solid state lighting; fluorescent lamps; LED; lighting installation.

---

### 1. Introduction

The artificial lighting is provided in all the places from inside the buildings in which conducting a production activity is necessary. When designing the lighting fixtures (Pasculescu, 2011), the regulated values will be ensured, regarding the lighting quantity meaning the lightings or the lighting levels and the lighting quality, more exactly the lighting uniformities, the luminance, the colours of the light etc. In order to distinguish the visual task (tasks), its modelling and accentuation, the luminous flux must be suitably directed to this (these). In this way the details of the visual task are accentuated, their visibility is increased, and the visual task is more easily to achieve.

The modelling (accentuation) is achieved from the proportion of the directed flow and the diffused flow. The directed flow must be directed in only one direction, but without being exaggerated, as a proportion to the diffuse one, in order not to create strong shadows and contrasts. The lightning systems must ensure the comfortable bright climate according to the requirements of that space, the visual task and the activities from it. This must be achieved without energy loss, but without favouring the aspects regarding the reduction of the energy consumption detrimental to the visual aspects of the lighting system (Pasculescu et al., 2017a), (Pasculescu et al., 2017b).

When choosing the light sources (the lamps) the designers must take into account the necessity to correctly render the colours, therefore, in the rooms where the colour rendering is necessarily required, lamps with colour rendering index are chosen depending to its destination.

In order to explore the advantages of the LED to the fluorescent tubes, we must firstly understand how the two lighting technologies work. The way they were designed and how they function are the attributes that determine pluses and minuses for each lighting technology.

The fluorescent tubes (neon) and their close akin, the compact economic light bulbs (Compact Fluorescent Light), function totally different to the LED. The fluorescent tube is made from a glass tube, with metal cap at each end, where the electric current flows. Inside the glass tube there is a small quantity of magnesium and inert gas (a gas that normally doesn't react to stimulus such as heat or electricity), usually argon (Ar). The inside of the glass tube is covered with a layer of phosphorus dust (Tanase, 2008), (Romanian Academy, 2005). When the electricity passes through the metallic

---

\* Corresponding author. Tel. +4-072-170-5284.  
E-mail address: pdragos\_74@yahoo.com.

contacts from the ends of the tube, it determines the excitement of the magnesium from inside the tube. The magnesium atoms release energy in the form of ultraviolet light, the light that is invisible to the human eye (Hu, 2017), (Jafari, 2016). When the ultraviolet light reaches the phosphorus layer, this layer starts to shine, creating the light (visible).

LED is the acronym Light Emitting Diode – The light emitting diode. Compared to the fluorescent and the incandescent lighting, the LED light bulb doesn't contain gases or filaments. The LED is made from a material named semiconductor. This material can be found in the nature in solid state (Sfetcu, 2016), therefore the LED is more durable. When the electric current flows through this semiconductor material, the electrons from the material access higher levels of energy and start to emit energy in the form of visible light.

## 2. The analyze regarding the lighting of a production hall

The maximum of the light spectrum  $\phi_\lambda$  of the human light is at 555,5 nm where the spectral sensitivity  $k_\lambda$  presents a unit value.

$$k_\lambda = \frac{\phi_\lambda}{p_\lambda} \quad (1)$$

The luminous flux  $\Phi$  can be determined from the relation

$$\Phi = \int_{380 \text{ nm}}^{760 \text{ nm}} \phi_\lambda \cdot d\lambda = \int_{380 \text{ nm}}^{760 \text{ nm}} k_\lambda \cdot p_\lambda \cdot d\lambda \quad (2)$$

The luminous efficiency  $\eta$  of a light source represents the ratio between the luminous flux  $\Phi$  emitted by the source, and the power absorbed from the electrical network  $P$  by the light source.

$$\eta = \frac{\Phi}{P} = \frac{\int_{380 \text{ nm}}^{760 \text{ nm}} \phi_\lambda \cdot d\lambda}{\int_0^\infty p_\lambda \cdot d\lambda} \quad (3)$$

The luminous efficiency is an economic indicator of a light source.

The reverse value of the maintenance factor  $M$  is the depreciation factor  $\Delta$  (table).

Table 1. The maintenance factor and the depreciation factor

The reduction of the light level due to dirt and aging of the lamps, to the lighting fixtures and to the walls of the room	The maintenance factor $M$	The depreciation factor $\Delta$
normal	0,8	1,25
increased	0,7	1,43
strong	0,6	1,67

The repartition of the lighting level on a surface is indicated through isolux curves. These result by joining the points with the same lighting level.

It was considered a production hall where, according to the regulatory norm NP-061-02, regarding the requirements of luxes on the useful plan (0 m) this being in the category of general traffic corridor, 150 luxes and colour rendering (Ra-0,8) are needed. Of course the hall contains more working areas such as: areas of mechanical reaming, areas of sheet bending, areas of manoeuvring the guillotine, where the regulatory norm NP-061-02 provides that the luxes needed on the useful plan (0,8 m), this being in the category of the metallurgical cutting, bending, marking, to be of 250 luxes and the colour rendering (Ra-0,8), and also in the areas of welding where 200 luxes are needed and the colour rendering (Ra-0,8).

The basic surface of the hall is around 800 m<sup>2</sup>, with a height of 5,2 m, the reflection degrees being for the ceiling 70%, walls 50%, floor 20%, and the maintenance factor of 0,80.

In a first phase lighting fittings with fluorescent tubes type CEAG 12267881103 eLLK 92058/58 CG-S were chosen, which have a luminous yield of 79,10%, a luminous flux of 8227 lm, 130 W power and a luminous efficiency of 63,3 lm/W (Fig.1).



Fig.1 Lighting fitting with fluorescent tubes type CEAG 12267881103 eLLK 92058/58 CG-S

Following the simulations that were performed, the luminous yield results for the lighting fittings with fluorescent tubes as it can be observed in (Fig. 2).

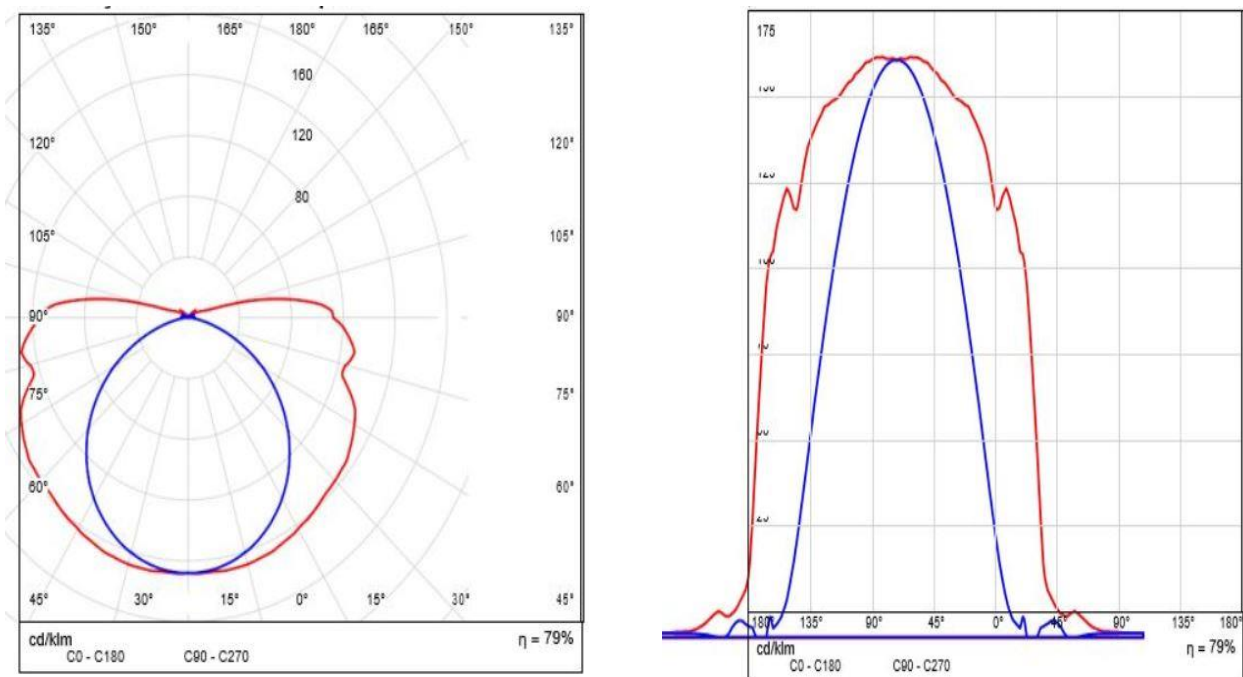


Fig.2 The luminous distribution at the lighting fittings with fluorescent tubes

Further on, lighting fittings with LED technology type ES-SYSTEM 7350301L LEDEX TOP 3000 were used, which have a luminous yield of 100%, a luminous flux of 17000 lm, 131 W power and a luminous efficiency of 129,8 lm/W illustrated in (Fig.3).

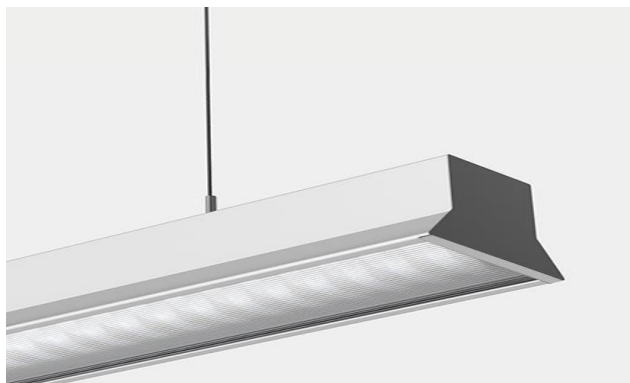


Fig.3 Lighting fitting with LED technology type ES-SYSTEM 7350301L LEDEX TOP 3000

Following the simulations that were performed, the luminous yield results for the lighting fittings with LED technology as it can be observed in (Fig. 4).

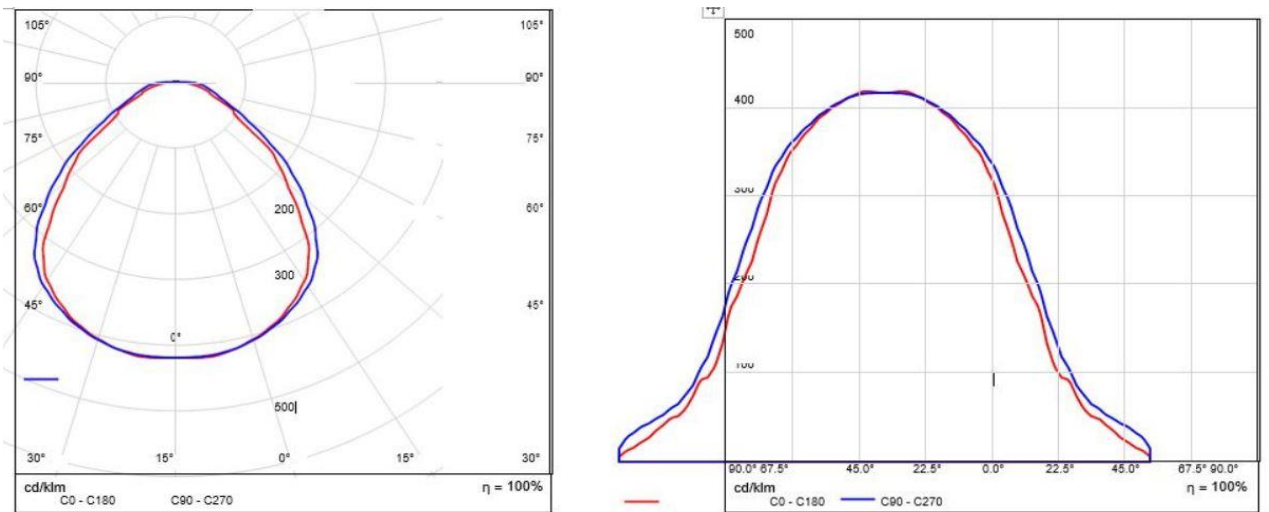


Fig.4 Luminous distribution lighting fittings with LED technology

According to the data that were used it can also be observed the intensity of the vertical lighting which is particularly important taking into account the fact that a qualitative lighting is wanted, from all points of view. As it can be also seen in (Fig. 5) and (Fig. 6) the number of luxes needed for each surface according to the normative (Masoud and Murnick, 2013, and Technical Norm, 2007) is by far much more satisfactory and uniform in the case of the lighting fittings with LED technology to the detriment of those with fluorescent tubes.

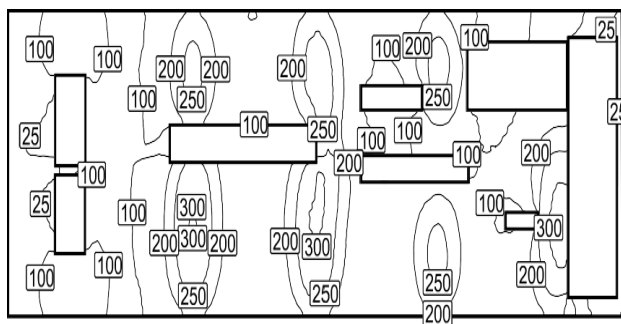


Fig.5 Isolines – lighting fittings fluorescent tubes [lx]

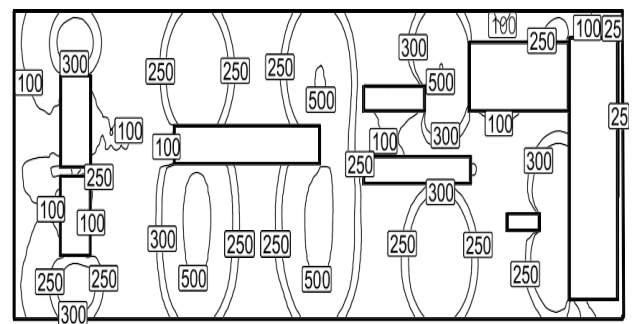


Fig.6 Isolines – lighting fittings LED technology [lx]

For a fast and easy interpretation of the calculation results, the false visualization of the colours helps pretty much. The settings of the colours false values are valid for the entire project, therefore they are also called "global false colours". The value set for a colour is used in all the diagrams and visualizations. (Fig 7) and (Fig. 8).

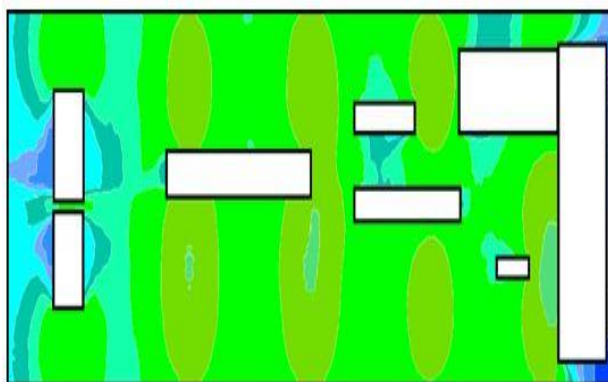


Fig.7 False colours – lighting fittings fluorescent tubes [lx]

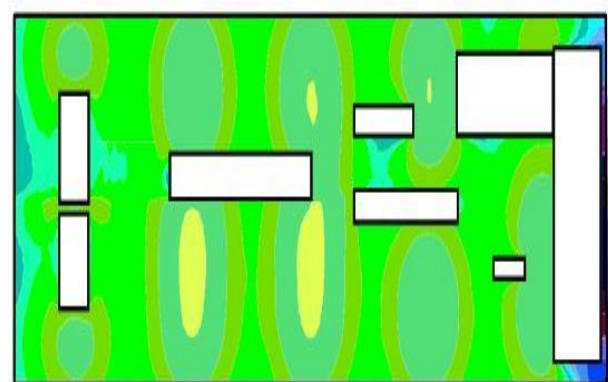


Fig.8 False colours – lighting fittings LED technology [lx]

For both implementations presented in the case study simulations were performed with the help of the professional software Dialux, in order to accordingly dimension the number of the lamps and their positioning, in the end resulting a number of 42 lighting fittings with fluorescent tubes and 36 lighting fittings with LED technology on the same useful plan, practically resulting, in time, a pretty consistent saving of electrical energy.

### **3. Conclusions**

The light generated by LED uses more efficiently the electrical energy than in the case of other light sources, the optic system that was used being superior in terms of losses. The efficiency of the power supplies is another very important factor. All these, cumulatively, lead to a much higher efficiency than the classical solutions. This will be reflected in the electricity consumption. The energy saving frequently exceeds 50% than the traditional sources. The life span of the LEDs (35.000-100.000 ore) substantially exceeds the one of the fluorescent light sources (8.000-15.000 hours). In addition, the light sources with LED are much more resistant to temperature variations, vibrations and mechanical shocks, therefore it is more reliable than the traditional ones. The LEDs don't need filters in order to produce the light of a certain colour. The colour is generated by the semi-conductor material.

The light is directed where it is needed. The traditional light sources emit the light in all directions. For many applications a great part of the light is wasted if no reflector or special optic device is used. The LEDs, being mounted on a plane surface, emit the light hemispherically therefore reducing the light that is not used.

When they are subjected to shocks and vibrations, their filament or the glass balloon are not damaged as it happens in the case of other types of lamps. The classical lamps with incandescence and gas discharge can be affected in the case of functioning in environments subjected to excessive vibrations. No warming time is needed. The fluorescent lamps, especially those based on amalgam need up to three minutes in order to get to the maximum of light emission. The lamps with high intensity discharge have warming times between a few minutes for the metallic halogens up to 10 minutes for the sodium lamps. They also need a supplementary time (10-20 minute) from the moment of their switching off until they can be switched on again, time interval that can be reduced to 2-8 minutes in the case of using the ballasts with pulse switching on. The LEDs reach the maximum brightness almost instantly and can be switched on again immediately after having been switched off.

The traditional lamps get broken more rapidly if they are subjected to frequent cycles of switch on-switch off because, in the case of the fluorescent and with gas discharge ones the switch on the switch on voltage erode the transmitter coating of the electrode. The life span of the LED and its luminous flux is not affected by the rapid cycles. This characteristic makes the lamps with LED to be adequate for applications with presence sensors or beacons.

The LED lamps are compatible with electronic control devices for the adjustment of the light level and of the colour characteristics. The efficient traditional light sources have limitations regarding the control of the illumination level (Argatu et al., 2010).

The LEDs for lighting do not emit –infrared or ultraviolet radiations. The fluorescent lamps convert about 20% from the energy into light, and the economic ones emit ultraviolet radiations that make necessary the presence of the special protection devices, in order not to affect the occupants of the room. The infrared radiations can produce burnings, and the ultraviolet ones damage the art objects, artefacts, cloth and the eyes. The LEDs conserve the energy and do not contain substances dangerous for the environment in contrast to the light sources with gas discharge that contain mercury. The much longer lifespan makes the LED light sources to be more attractive in terms of environmental protection.

The main disadvantage of the LED light bulbs is the higher price compared to other models. Such a light bulb generally costs a few dozens of lei more than other types of light bulbs. Therefore, the lighting of a production hall with LED light bulbs could prove to be an expensive investment. However, the price will pay for itself pretty fast through the significantly reduced energy consumption.

It was demonstrated that buying a lighting system with LED linear lamps becomes in time a profitable investment due to the decreased costs of the energy and due to the lack of the maintenance activities over the life of the LED.

The world trend is to give up the classical light sources, that are not energetically efficient and to promote the high performance light source, category that the LEDs belong to. The European legislation provides that until 2020 the lighting sources with incandescence and with gas discharge to be replaced.

In EU, the total consumption of the internal lighting is of approximately 86 TWh and it is expected to increase to 102 TWh until 2020. The widespread implementation of the SSL technologies could significantly contribute to the achievement of the Europe 2020 Strategy objectives for an intelligent, durable increase and favourable to the inclusion, especially for achieving the target of increasing the energetic efficiency (until 2020: increase with 20% of the energetic efficiency to the levels from 1990). It would have a significant impact on the European users (both consumers and professional users) and on the competitiveness of the European lighting industry.

## References

- Argatu, F. C., Cepisca, C., Bardis, N., Seritan, G., *Measures and control used in public lighting*, (in Romanian), Electra Publishing House ICPE, Romania, (2010).
- Hu, C.X., Design and Optimization of the Lighting Environment for the Brand Clothing Stores Based on DIALUX Software, *2nd International Conference on Materials Science, Machinery and Energy Engineering*, (2017).
- Jafari, H. K., DIALux Space to Height index for Surface Circular Light Sources, *3rd National and First International Conference in applied research on Electrical, Mechanical and Mechatronics Engineering*, (2016).
- Masoud, N., Murnick, D. E., High Efficiency, *Fluorescent Excimer Lamps, an Alternative to CFLs and White Light LEDs*, *Journal of Light & Visual Environment*, Vol. 37, Issue 4, pp. 171-175, (2013).
- Pasculescu, D., *Electrical installations – project guidance*, (in Romanian), Universitas Publishing House, Romania, (2011).
- Pasculescu, V.M., Vlasin, N.I., Florea, D., Suvar, M.C., *Improving the quality of the process for selecting electrical equipment intended to be used in potentially explosive atmospheres*, *Quality-Access to Success*, Vol. 18, S1, pp. 97-102, (2017).
- Pasculescu, V.M., Vlasin, N.I., Suvar, M.C., Lupu, C., *Decision support system for managing electrical equipment used in hazardous atmospheres*, *Environmental Engineering and Management Journal*, Vol. 16, Issue 6, pp. 1323-1330, (2017).
- Romanian Academy, Commission of Terminology for Exact Sciences, *Explanatory dictionary romanian/english/french for electro-technics ELTH 18, Illumination technique*, (in Romanian), AGIR Publishing House, Romania, (2005).
- Sfetcu, N., *LED lighting in the EU and Romania*, (in Romanian), edited by Sfetcu Nicolae, (2016).
- Tanase, S., *Lighting tools*, (in Romanian), Humanitas publishing house, Bucharest, Romania (2008).
- Technical Norm, *NP 061-02 technical norms for the design and execution of artificial lighting systems in buildings*, Bucharest Technical University of Constructions, Fast Print Publishing House, (2007).

## Quality management algorithm used in a programmable microcontroller as Maximum Power Point Tracker

Marius-Daniel Marcu<sup>a\*</sup>, Florin Gabriel Popescu<sup>a</sup>, Titu Niculescu<sup>a</sup>, Razvan-Ioan Slusariuc<sup>a</sup>,  
Maria Daniela Stochitoiu<sup>a</sup>

<sup>a</sup>University of Petrosani, Petrosani Universitatii 20, 332006, Romania

---

### Abstract

The energy output of the Sun is fairly constant, but the solar irradiance varies significantly from one hour to another and changes throughout the day. In this paper we are presenting the design of a simple MPPT (Maximum Power Point Tracker) charge controller based on perturb and observe algorithm embedded into Atmega 2560 microcontroller. The voltage of the solar panels operating at their peak power point at Standard Testing Conditions is 25C° is higher than the battery's voltage. As solar module operating temperature goes down, the voltage increases so the MPPT controller is able to capture the excess module voltage to charge the batteries. As a result, a MPPT controller in low temperature conditions can produce up to 30%. The charge controller will use the microcontroller, DC-DC buck boost circuit, sensors that will read the electrical information from the photovoltaic panel and the battery.

*Keywords:* algorithm; tracking; controller; conversion; photovoltaic.

---

### 1. Introduction

The energy output of the Sun is fairly constant, but the solar irradiance varies significantly from one hour to another and changes throughout the day. Sunlight sometimes only reaches the parts of the panels that are facing the Sun at a given time, and the most intense irradiance is experienced by those parts that are not shadowed from the Sun. The other significant factor that modifies the conversion is the temperature at the surface of the PV.

So this problem can be solved by a battery charge controller but in two quite different ways. Maximum Power Point Tracking method, frequently used as MPPT, is an electronic system that operates the PV modules in a way that allows the modules to inject all the power they are capable of.

### 2. The design of the MPPT system

We are presenting the design of a simple but effective MPPT charge controller based on ATmega 2560 microcontroller (Figure 1).

The charge controller will house the microcontroller and DC-DC buck boost circuitry in addition to the sensors that will read the electrical information from the photovoltaic panel and the battery.

The charge controller will measure the voltage and current of both the solar panel and battery bank. Using this sensor information, a regulated output will be delivered to the battery bank. The goal is to have efficient charging of the battery bank using the MPPT algorithms implemented in software by the microcontroller (Hohm and Ropp, 2003).

Similarly, the current sensors send an analog voltage value to the microcontroller, which will determine the nominal value of the current. The current sensors will function alongside the voltage sensors to sense current coming into and out of the charge controller.

---

\* Corresponding author. Tel.: +40-724-561-150.  
E-mail address: mariusmarcu66@yahoo.com.



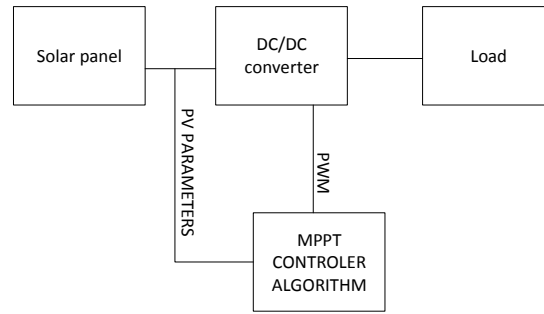


Fig. 1. Block diagram of Typical MPPT system

### 3. Perturb and observe algorithm

One of the most efficient method is “perturb and observe” algorithm. Using the MPPT algorithm when solar radiation intensity is changing, there is an increase in the collection of energy (Rekioua and Matagne, 2012).

In Figure 2 and 3, the P&O algorithm and the related schematic are presented. The way to find MPP is by repeated attempts, by modifying the voltage at the generator terminals and comparing the power delivered in this case with the power from the previous step.

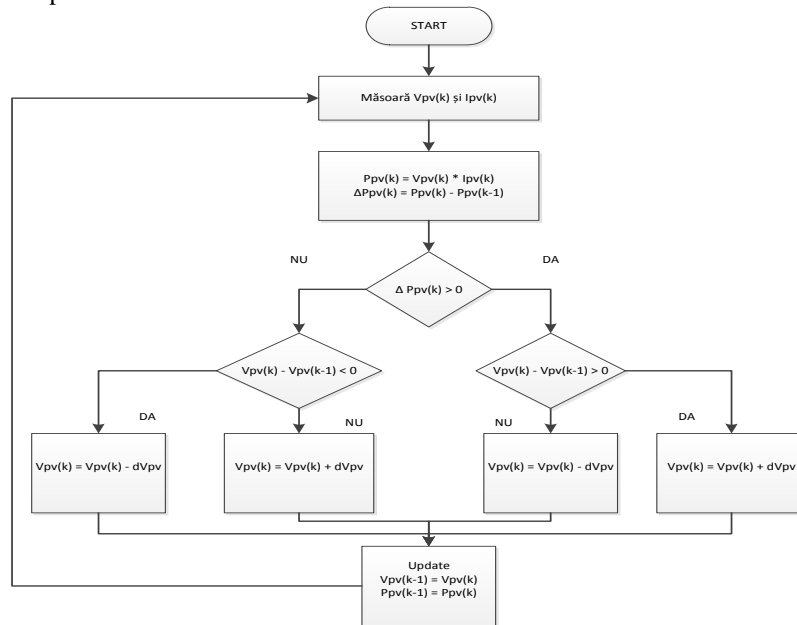


Fig. 2. Perturb and observe algorithm

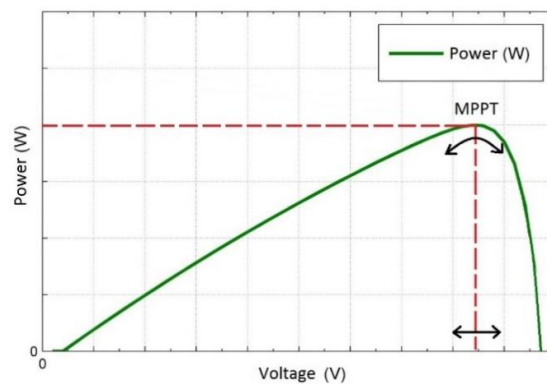


Fig. 3. MPPT working logic

If the power at the current step is higher, the voltage change continues in the same direction, and if not then it is modified in the other way. This method of finding the maximum point leads to oscillations around this point, even in stationary conditions, and in the case of sudden change of solar radiation, it can even lead to searching in the opposite direction of the maximum power point (Marcu et al., 2014), (Cabal et al., 2007).

#### 4. Reading parameters of the photovoltaic panel

A key part of the system is the sensor block that senses the current and the voltage of the PV. Sensors then send the voltage and the current information into the microcontroller and therefore it compares them with the preset instruction and changes them accordingly.

##### 4.1. Voltage reading

Using low voltages, the circuit needs only up to 25V sensor. Therefore, the voltage on the PV panel is read with a simple voltage divider as presented in the figure 4:

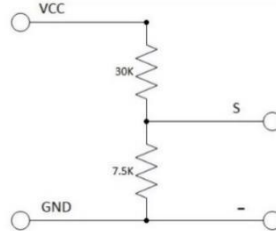


Fig. 4. Voltage sensor schematic

The code that was implemented into the microcontroller that will read the voltage info is shown below:

```

int analogInput = A1;
float vout = 0.0;
float vin = 0.0;
float R1 = 30000.0;
float R2 = 7500.0;
int value = 0;

void setup(){
    pinMode(analogInput, INPUT);
}

void loop(){
    value=analogRead(analogInput);
    vout=(value * 5.0) / 1024.0;
    vin=vout / (R2/(R1+R2));
    delay(500); }
Serial.begin(9600);

```

Calibration of this sensor is made by accurately measuring the values of the two resistors of 7.5K and 30K ohms, modifying the values in the program accordingly.

##### 4.2. Current reading

For current measurement we used a hall effect current sensor (Figure 5). The ACS711 sensor read the current value and convert it into a relevant voltage value. The value that links the two measurements is sensitivity. The sensor can measure positive and negative currents.

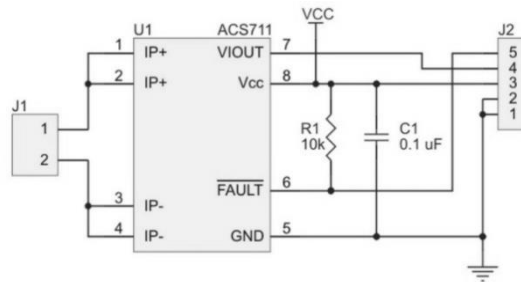


Fig. 5. Current sensor schematic

The current according to the voltage value is determined by the relations:

$$V_{out} = \frac{V_{cc}}{2} + i \frac{V_{cc}}{36.7} \quad (2)$$

$$i = 36.7 \cdot \frac{V_{out}}{V_{cc}} - 18.3 \quad (3)$$

where:

- $i$  - is the measured current
- $V_{OUT}$  - is the voltage given by the sensor directly proportional to the value of measured current
- $V_{cc}$  - is the logic supply voltage of 5V

The code that was implemented into the microcontroller that will read the voltage info is shown below:

```
const int analogIn = A0;
int mVperAmp = 185;
int RawValue = 0;
int ACSOffset = 2500;
double Voltage = 0;
double Amps = 0;

void setup(){
    Serial.begin(9600);
}

void loop(){
    RawValue = analogRead(analogIn);
    Voltage = (RawValue / 1024.0) * 5000;
    Amps = ((Voltage - ACSOffset) /
    mVperAmp);
    delay(2500);
}
```

The current value is given by the Amps variable in the code and it's processed by the microcontroller to evaluate the power given at the generator terminals.

## 5. Description of the circuit

A microcontroller cannot turn on a MOSFET transistor as it cannot supply enough current to charge the MOSFET because its gate is capacitive. That is why a MOSFET driver will be used. The driver itself will supply the current that the transistor will need (Figure 6). As we are using DC converter the PWM signal will be applied with respect to transistor source (Rekioua and Matagne, 2012).

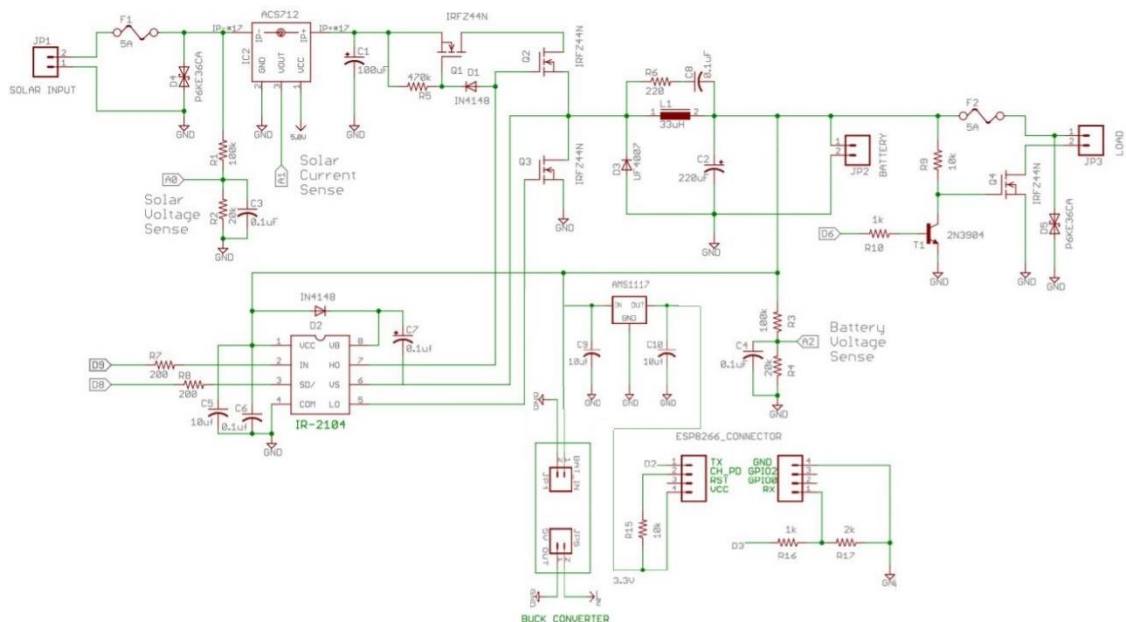


Fig. 6. The circuit connected to the Atmega 2560 microcontroller

The voltage and the current sensors provide the values to the microcontroller which based on the algorithm will send a signal according to the DC converter.

Switching of a DC-DC converter need two of operation: a controller stage and a power stage. The controller stage supervises the precision of power supply stage by regulating voltage. Therefore, pulse width modulation technique is introduced here for regulating the voltage.

PWM refers to the method of achieving analog signal by digital means. In this system we are using a microcontroller and also switching mechanism is involved so PWM technique has been integrated. PWM works by changing the duty cycle ratio of the switches to produce a constant output voltage.

The microcontroller configuration will be connected to a computer, allowing it to communicate via USB with the baud rate set at 9600bit/s. The serial data that is received will be stored to laptop.

After testing the PV system exposed to the Sun, the most conclusive data is shown in the figure 7. The measurements were made on a polycrystalline 30W photovoltaic panel.

The testing conditions were for the nominal irradiation of 1000 W/m<sup>2</sup> since the region is rated at this irradiance during the peak solar position. And temperature of the ambient air was around 20 °C, the short circuit current is about 300 A/m<sup>2</sup>.

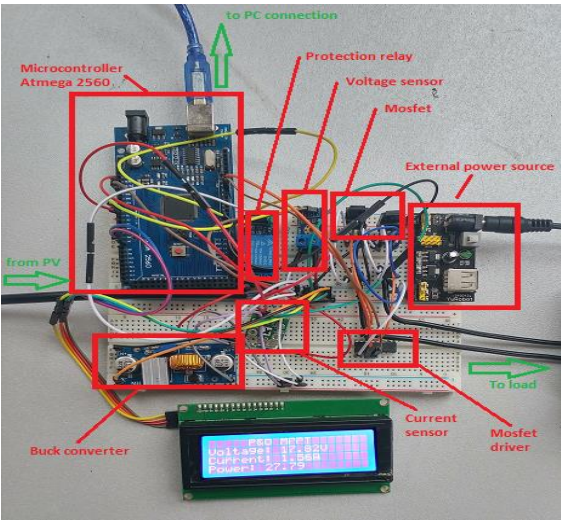


Fig. 7. The physical MPPT circuit

For different temperatures, the short circuit current has to be modified by 0.2% for every 1°C. The efficiency of the solar panel has been calculated at different values of the panel temperature.

Table 1. Calculated temperature versus Efficiency of the polycrystalline photovoltaic panel

Temperature	28°C	50°C	60°C	70°C
Efficiency	9.6%	8.9%	8.2%	7.1%

The power provided by the photovoltaic panel to the battery is presented in figures 8-11 for different temperatures.

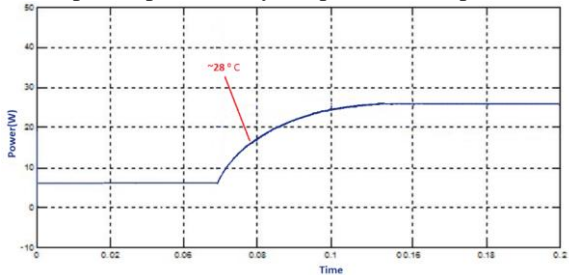


Fig. 8. The power provided by the photovoltaic panel to the battery as the working MPPT circuit is working at ~28° C

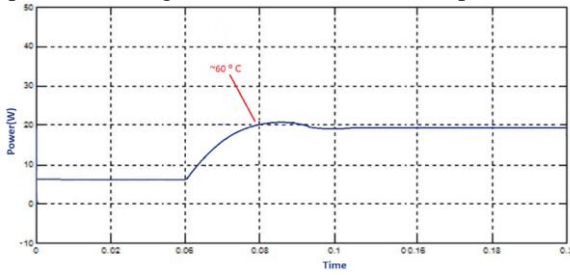


Fig. 10. The power provided by the photovoltaic panel to the battery as the working MPPT circuit is working at ~60° C

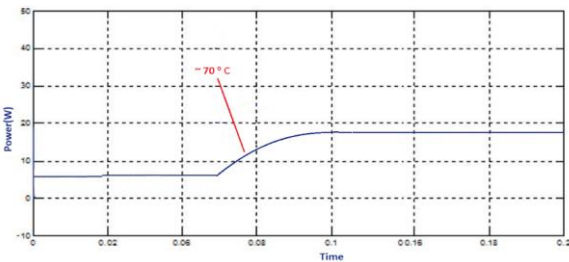


Fig. 9. The power provided by the photovoltaic panel to the battery as the working MPPT circuit is working at ~70° C

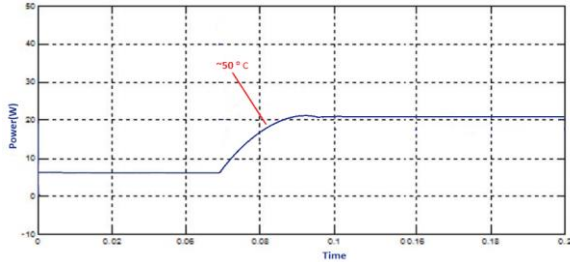


Fig. 11. The power provided by the photovoltaic panel to the battery as the working MPPT circuit is working at ~50° C

Since the testing of the circuit with operating MPPT algorithm requires only a short time, we have been selected the moment when the algorithm is turned on, so on the selected timescale the P&O algorithm is started at ~0.07 and the power delivered by the charge controller to the battery bank is increasing steadily to a point where it reaches a flat region characterized by the nominal data of the photovoltaic panel when the measurement was made at ~28°C at the surface of the panel.

If the measurement is made at different temperatures it shows how the P&O algorithm is useful due to lower temperature of the panel. At 28 degrees the circuit and microcontroller manages to absorb more power from the panel compared to the other 3 measurements, at 50°C, 60°C, 70°C.

When the operating point is not close to the maximum power point, high perturbation levels are made, and little levels are made if in near to the MPP. So the algorithm has to know the position of the maximum power point. Also, the exact spot of it is not necessary due to the fact that this algorithm will work near the real maximum power point. In this method, the level of the perturbation is determined by the equation:

$$\Delta V(V) = f(V_{M,est} - V) + \Delta V_{min} \quad (3)$$

- $\Delta V$  - is the perturbation step;
- $V_{M,est}$  - is the estimated voltage at MPP;
- $V$  - is the measured voltage;
- $\Delta V_{min}$  - is the minimum value of the perturbation.

From the images above it can be observed that after starting the MPPT algorithm in the microcontroller, the charge controller manages to inject a much higher power into the battery, proving that the use of this method is resourceful.

## 6. Conclusion

The use of a microcontroller has its advantages as low cost of production and reliability. It provides a simple and efficient design of a solar charge controller and DC-DC converters bring a significant improvement in overall system performance and are thus considered a key device in designing such a photovoltaic system. This Atmega2560 microcontroller is widely available and through the C programming language becomes a very flexible and useful tool for improving the energy management of a photovoltaic system.

Ensuring good conversion of solar energy into electricity depends both on the use of high-efficiency components within the photovoltaic system as well as the planning and design of the system. Right after the MPPT algorithm is starting, the power provided by the circuit is increased significantly. Therefore, an increase of the power generated by the PV panel can be observed in the measurements.

## References

- Cabal, C., Alonso, C., Cid-Pastor, A., Estibals, B., Segulier, L., Leyva, R., Schweitz, G., Alzieu, J. *Adaptive digital MPPT control for photovoltaic applications*. In Proceedings of the ISIE, Vigo, Spain, 4–7 June, (2007).
- Hohm, D., Ropp, M. *Comparative study of maximum power point tracking algorithms*. Progress in photovoltaics, Research and Applications, 11, pp. 47–62, (2003).
- Marcu, M., Popescu F., Pană L., Slusariuc I.R. Modeling and simulation of a photovoltaic module using the two diode model, *SGEM International Conference*, Albena, (2014).
- Rekioua, D., Matagne E., *Optimization of Photovoltaic Power Systems*, Hardcover, XII, pp. 283, (2012).

# Improving the quality of measurements in electrical processes using NI USB data acquisition systems

Titu Niculescu<sup>a\*</sup>, Florin Gabriel Popescu<sup>a</sup>, Marius Marcu<sup>a</sup>, Ioan Razvan Slusariuc<sup>a</sup>

<sup>a</sup>University of Petrosani, Petrosani Universitatii 20, 332006, Romania

---

## Abstract

For the study, the evaluation and visualization of switching processes, modern computer-aided measurement elements associated with high-speed data acquisition systems are used. In the paper is presented a method of study of switching phenomena using a NI USB data acquisition system produced by National Instruments. It is well known that the acquisition software provided by the manufacturing company is LabView. In the paper is presented a more efficient alternative method, based on the use of MATLAB software, and a design interface circuit attached to the NI USB system. In industrial electrical installations frequently occur situations where inductive circuits are connected to alternating current sources. Two methods of data acquisition are presented in the paper. The first method to study this, is the acquisition of data using a MATLAB program designed for the interface circuit presented in the paper and the NI USB data acquisition system. The second method of measurement is based on the use of the Simulink program package. Because there is no support software for data acquisition in Simulink in 64-bit systems, the paper presents a method that does this. The measurement method highlights its superiority compared to the use of LabView software. In the paper, both aspects of the switching are addressed, both by connecting an inductive circuit to an alternative voltage source and by disconnecting it from the source.

**Keywords:** coil; connection; data acquisition; diagram; disconnection; NI USB; MATLAB; Simulink.

---

## 1. Introduction

In industrial electrical installations frequent switching of inductive circuits occurs at alternating voltage sources, this phenomenon leading to the occurrence of transient modes that may become dangerous under certain conditions. At the coil terminals they often cause overvoltages that can become dangerous if they are not evaluated and no specific action is taken. In the paper is described a modern method of analysis of such modes based on the use of a high resolution data acquisition system produced by National Instruments and the MATLAB software. For the measurements, an interface circuit was designed, which takes the electrical signals and introduces them into the acquisition system connected to the PC. Two representative situation of an inductive circuit for different circuit inductance values were considered for the study.

As it is known, the software provided by National Instruments, for such applications is the LabView. In the paper, the switching phenomena of inductive loads are studied with MATLAB software. The superior processing capabilities of the results are well known by using this software, compared to the one provided by the DAQ system maker.

In the beginning of the paper is presented the theoretical phenomenon that considers ideal circuit elements, both when connecting and disconnecting an inductive circuit. To achieve this goal is presented in the paper a circuit of its own design interface, which make the connection between the circuit-specific electrical quantities and the NI USB 6003 data acquisition system.

Two methods of data acquisition are presented in the paper. The first method is based on programming. A MATLAB program was developed that drives the data acquisition process and is presented in the paper. It generates, along with the whole system, the variation diagrams of voltage, current and instantaneous power on the coil.

The second measurement method is based on the Simulink program package. As is well known, MathWorks provides support software for data acquisition in Simulink for 32-bit systems only. In the last part of the paper is presented a procedure that makes possible the acquisition of data in Simulink on 64-bit systems.

---

\* Corresponding author. Tel.: +04-723-922-072.  
E-mail address: niculescu\_titu@yahoo.com.

In the conclusions, the differences between the theoretical situation described in the paper and the practical result of the measurement process are highlighted. It is emphasized the use of this acquisition method in studying fast electrical processes.

## 2. Theoretical considerations

### 2.1. Connection mode

It is considered an inductive resistance circuit R and inductance L that initially connects to an alternating voltage source (Niculescu, 2012a), (Niculescu, 2012c):

$$e(t) = \sqrt{2}E \sin(\omega t + \beta) \quad (1)$$

If the parasitic capacities and the power supply cable capacity are neglected and circuit elements are considered to be ideal, the expression of the transient current in the circuit is:

$$i(t) = \sqrt{2}I \sin \left[ \sin(\omega t + \beta - \varphi) - \sin(\beta - \varphi) \cdot e^{-\frac{t}{T}} \right] \quad (2)$$

is the actual value of the current and  $\varphi$  is the phase difference between the voltage at the coil terminals and the current in the circuit.

The voltage at the coil terminals during the transient mode has the expression:

$$u_L(t) = \sqrt{2}LI \left[ \omega \cdot \cos(\omega t + \beta - \varphi) + \frac{1}{T} \sin(\beta - \varphi) \cdot e^{-\frac{t}{T}} \right] \quad (3)$$

### 2.2. Disconnection mode

It is considered an inductive circuit with a resistance R and inductance L that is powered by an alternating voltage source and at initial moment it is disconnected. It is believed that the disconnection is done when the current is zero, and the voltage source has the expression:

$$e(t) = U_m \sin(\omega t + \varphi) \quad (4)$$

Where  $U_m$  is the voltage amplitude and  $\varphi$  is the phase difference between the voltage and the current in the inductive circuit.

If the real case is considered where the power cord has C capacity, the electrical scheme of the circuit with concentrated parameters is presented in fig.1.

At the initial moment it is considered that the circuit breaker k opens.

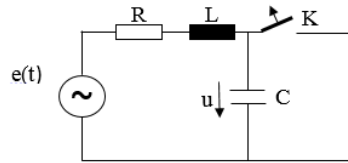


Fig. 1. The electrical scheme of the disconnected circuit

The differential equation of the voltages in the circuit is:

$$R \cdot i + L \frac{di}{dt} + u = e(t) \quad (5)$$

Laplace transform applied to the circuit leads to obtaining the expression of disconnection current that takes the form (Golovanov et al., 2009):

$$i = I_m \cdot \cos(\omega t + \varphi - \phi_1) + \frac{DU_m e^{-\delta t}}{2\omega_e L} \cdot \left[ \cos(\omega_e t - \gamma) - \frac{\delta}{\omega_0} \sin(\omega_e t - \gamma) \right] \quad (6)$$

Transient voltage at the coil terminal takes the following form:

$$u_L(t) = L \frac{di}{dt} = \frac{D \cdot U_m}{2} \left[ \left( \frac{\omega_p}{\omega_e} \right)^2 e^{-\delta t} \cdot \sin(\omega_e t - \gamma) - 2 \frac{\delta}{\omega_e} e^{-\delta t} \cdot \cos(\omega_e t - \gamma) \right] - I_m \omega L \cdot \sin(\omega t + \varphi - \phi_1) \quad (7)$$



### 3. Interface circuits

For the experimental evaluation of electrical quantities, a NI-USB 6003 data acquisition system was used with a 100kS sampling rate produced by National Instruments, and the software environment used is the MATLAB program. To make the measurements, it was necessary to design an interface circuit that takes the electrical quantities from the inductive circuit and transfer it to the data acquisition system. The circuit of the interface is presented in figure 2, (Niculescu, 2012b).

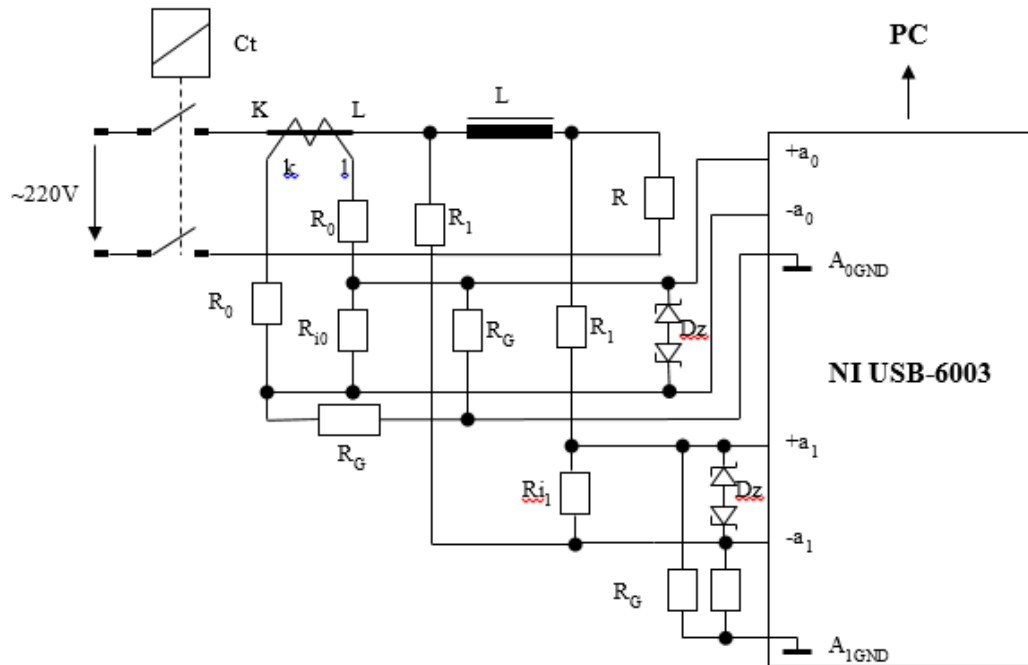


Fig. 2. The electrical circuit of the measurement system

To avoid the connection of the voltage phase directly to the input of the acquisition system, symmetrical voltage dividers were used at which  $R_{i0}$  and  $R_{i1}$  resistors are connected in parallel with the inputs of the measurement system  $a_0$  and  $a_1$ . The drops voltage on these resistors are proportional to the inductive voltage and current in the circuit. For the protection of analog inputs against destructive surges which exceed the range  $-10V \dots +10V$ , four  $D_z$  Zenner diodes have been used, (Loackahart and Tilleson, 2017), (NI USB-6001/6002/6003 User Guide), (Maurizio 2013).

### 4. Measuring process in MATLAB

Measurements were made with the NI-USB 6003 data acquisition system with a 100kS sampling rate. The software used was MATLAB 2014b which, prior to the measurements, required the creation of a specific program for the acquisition process. It allows the acquisition of electrical signal from the interface and the display of the variations of voltage on the coil, the current in the circuit and the instantaneous power dissipated on the coil. The MATLAB program allows you to trace induction voltage variation and inductive current curves on the same graph and instantaneous power curve (Mendel, 2016), (Loackahart and Tilleson, 2017), (Software Matlab 2014b).

As can be seen from the program, it has three groups of instructions. The first group makes it possible to acquire the data for 1.5 seconds for two measurands, each with a sampling rate of 45000S.

The second set of instructions generates the inductive voltage and current circuits in the circuit on the same graph, and the third generates the instantaneous power diagram dissipated on the coil.

Two constants with values of 163 and 27 were used in the program.

These were determined experimentally, taking into account the resistance values in the resistive dividers and the fact that the physical measurement system has a finite input impedance.

### 5. Experimental Results

The measurements were made for two values of the coil inductance. The following circuit parameter values were used for the first measurement:

- $L=12\text{mH}$ ;  $R=100\Omega$ ;  $U=220\text{V}$ .

For the situations of connection and disconnection several diagrams were plotted with the voltage and current variations, but also instantaneous power dissipated on the coil.

For the situation of connecting of an inductive load to an alternating power source, the following diagrams were obtained:

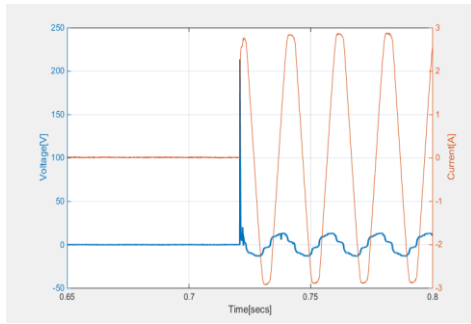


Fig. 3. Voltage variation on the coil and the current at connecting for  $L=12\text{mH}$

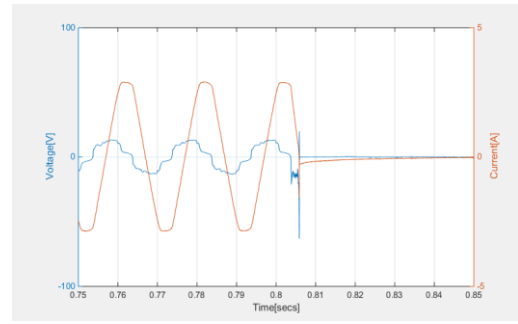


Fig. 5. Voltage variation on the coil and the current at disconnecting for  $L=12\text{mH}$

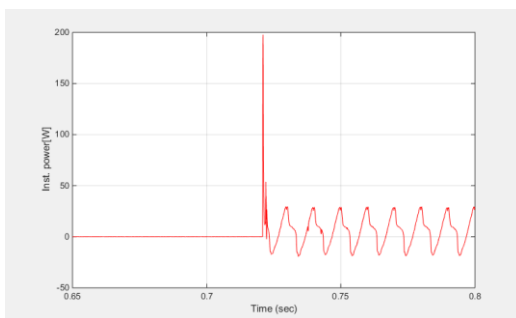


Fig 4. Instantaneous power variation on the coil at connecting for  $L=12\text{mH}$

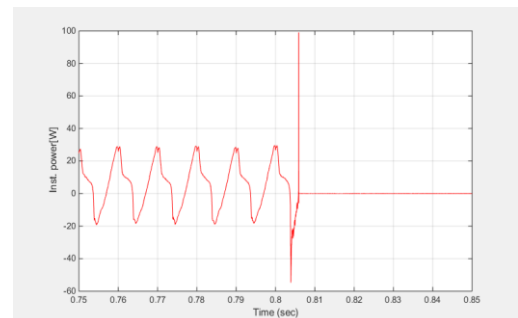


Fig. 6. Instantaneous power variation on the coil at disconnecting for  $L=12\text{mH}$

In the case of connecting of the inductive circuit is observed and commutation overvoltage that appears immediately after closing the circuit. The value of this overvoltage is dependent of the value of circuit's inductivity. It has to be remembered that this overvoltage is not constant in all the measurements that were made, it depends on the moment of disconnecting the circuit. This overvoltage is also reflected in the instantaneous power curb at the coil terminals. The peak of the inductive voltage leads to the apparition of a power spike, right after connection. Several measurements were made and the most representative case was presented here (Marinov and Valchev 2010).

In the care of disconnecting the circuit the following diagrams were obtained:

At disconnection point is observed the appearance of a commutation overvoltage right after disconnecting the circuit from the power source. The value of the overvoltage is dependent of the inductivity of the circuit. This overvoltage is not constant in all the measurements we made, for it depends of the moment of disconnecting the circuit. This overvoltage is also reflected in the instantaneous power curb at the coil terminals. The peak of the inductive voltage leads to the apparition of a power spike, right after disconnection. Out of the all the measurements that were made, the most representative case was presented here.

## 6. Measuring process in SIMULINK

Another method of measuring and studying switching phenomena is the data acquisition in Simulink. This paragraph presents a new and modern method to study the transient phenomena that occurs when switching the inductive charges to an AC power source, using the MATLAB-SIMULINK software package. It is known that NI-USB data acquisition systems manufactured by National Instruments are not recognized by the Simulink software package in 64-bit systems. That is why a 32-bit system is obligatory. From this point of view, the paragraph presents a method by which this disadvantage is eliminated, making the data acquisition process possible in Simulink software package in 64-bit systems (Software Matlab 2018a).

Experimental measurements were made with a data acquisition system type NI USB-6003 with a rate of  $100\text{ks/sec.}$ , and the measurements were processed by 2018a MATLAB version, which recognizes only data acquisition system in MATLAB, not in Simulink.

At this moment the Data folder from the Workspace can be read from a Simulink simulation model. This is shown in Figure 7 (Eshkabilov 2016):

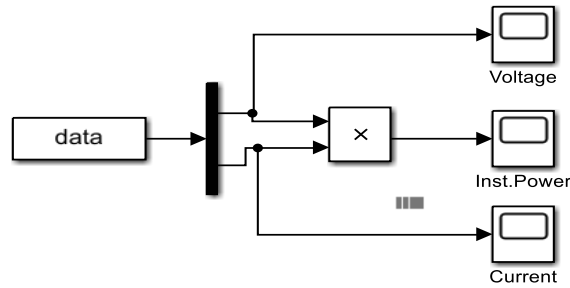


Fig. 7. Simulink model for study the transient phenomena

The application of the previously described process has led to the experimental results described below. Because the transient phenomena are less significant in the current variation curve, it was chosen to show only the voltage variation at the coil terminals and the instantaneous power dissipated thereon. The situation of connecting and disconnecting an inductive load has been considered (Karris 2011).

For electrical parameter values:

- $L=12\text{mH}$ ;  $R=100\Omega$ ;  $U=220\text{V}$ , the following diagrams were obtained:

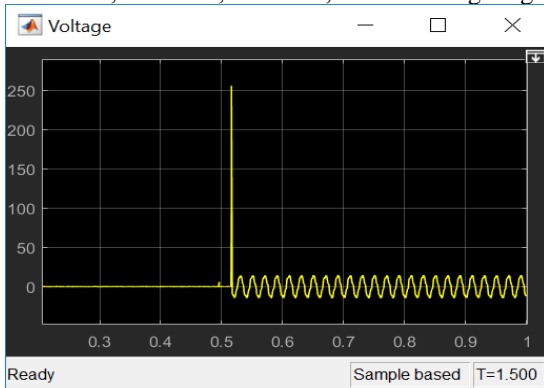


Fig. 8. Voltage variation on the coil at connecting for  $L=12\text{mH}$

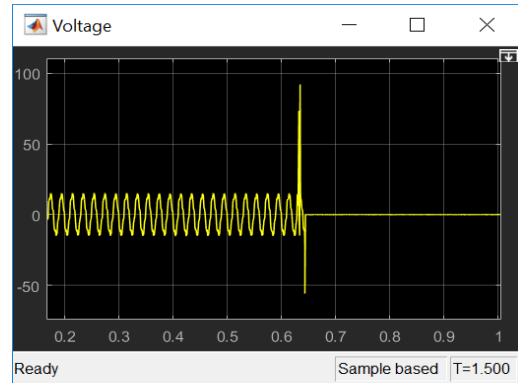


Fig. 10. Voltage variation on the coil at disconnecting for  $L=12\text{mH}$

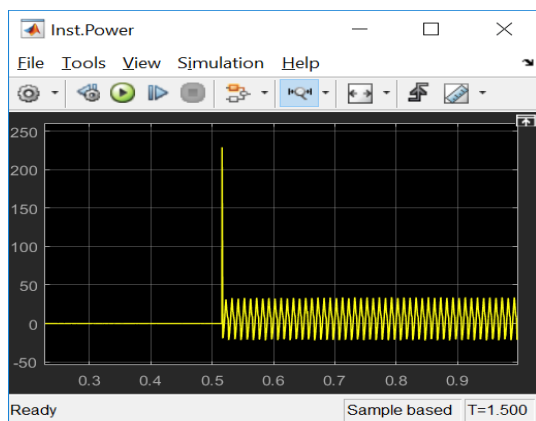


Fig. 9. Instantaneous power variation on the coil at connecting for  $L=12\text{mH}$

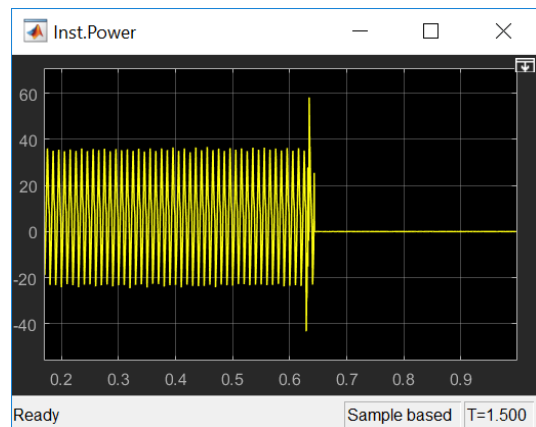


Fig. 11. Instantaneous power variation on the coil at disconnecting for  $L=12\text{mH}$

## 7. Conclusions

The diagrams presented in the paper show that when switching inductive circuits to an alternative voltage source, there is a very high slope overvoltage that can become dangerous for the physical elements of the circuit. This voltage peak is dependent on the value of the inductance and the moment of the circuit switching. Various measurements were chosen from the most representative cases. From the measurements made it was observed that the ratio between the overvoltage and the voltage on the coil prior to switching is the higher when the value of the inductance decreases. Also, the duration of the overvoltage pulse decreases as the inductance decreases.

The method of study of the switching phenomenon of inductive loads to alternative voltage sources based on the use of data acquisition systems is a modern one and allows for focusing on the event at any time of the transient switching mode.

The electrical capacities that appear in the circuit in the real situation make the diagrams obtained by the measurements to be different from the theoretical situation presented in the paper, where the phenomenon was presented and these capacities were neglected, the elements of the circuit being considered ideal. Their presence leads to the emergence of short-duration oscillating modes and very high amplitude compared to the permanent regime.

The measurement method is based on the use of the MATLAB program that has the possibility of further processing of the results of the measurements with superior accuracy, compared to those resulting from the use of the LabView software provided by the manufacturer.

It is necessary to mention that high-speed data acquisition systems are required for the study of fast electrical processes. The NI USB 6003 Data Acquisition System, which has a sampling rate of 100kS, is sufficient to study such switching phenomena.

As presented in the paper, a modern and efficient method of studying these kinds of phenomena is based on data acquisition in Simulink. Subsequent possibilities of processing the results through this method are huge. MATLAB 2014b software was used for data acquisition, and MATLAB 2018a was used to process the results. Two versions of MATLAB were used, as the latter does not have support software for NI USB data acquisition systems, but has superior processing capabilities for data acquisition results.

## References

- Eshkabilov, S. L., *MATLAB/Simulink Essentials: MATLAB/Simulink for Engineering Problem Solving and Numerical Analysis*, Publisher Lulu.com, ISBN: 1483458067, 9781483458069, (2016).
- Golovanov, N., Ionescu, I., Mira, N., Postolache, P., Toader, C., *Electrical energy consumers. Materials. Measurements. Electrical devices. Instalations. (in romanian)*, Editura AGIR, Bucuresti, pp.628; ISBN: 978-973-720-240-6, (2009).
- Karris, S. T., *Introduction to Simulink: With Engineering Applications*, Publisher Orchard Publications, ISBN: 1934404217, 9781934404218, (2011).
- Lockhart, S., Tilleson, E., *An Engineer's Introduction to Programming with MATLAB 2017*. Publisher: SDC Publications, ISBN: 1630571253, 9781630571252, (2017).
- Maurizio, P.E., *Data Acquisition Systems: From Fundamentals to Applied Design*, Publisher: Springer, ISBN-10: 1461442133, ISBN-13: 978-1461442134, (2013).
- Marinov, A., Valchev, V., *Improved methodology for power loss measurements in power electronic switches using digital oscilloscope and MATLAB*. 14th International Power Electronics and Motion Control Conference (EPE/PEMC), 6-8 Sept., (2010).
- Mendel, H., *Matlab and Simulink. Working with Blocks*. Publisher Create Space Independent Publishing Platform, ISBN: 1539327728, 9781539327721, (2016).
- Niculescu, T., Chapter 2: Study of Inductive-Capacitive Series Circuits Using the Simulink Software Package, In *Technology and Engineering Applications of Simulink*, Publisher: InTech, Published: May 23, under CC BY 3.0 license, in subject Technology, ISBN 978-953-51-0635-7, (2012).
- Niculescu, T., *Study of transient phenomena using NI-USB data acquisition systems in Matlab Simulink medium on 64 bit operating systems*, Journal of Advanced Computer Science & Technology, pp.198-203, DOI: 10.14419/jacst.v4i1.4518/2015, (2015).
- Niculescu, T., *Transitory phenomena in capacitive circuits connected to a AC source* – Proceedings of the 4 th International Conference on Circuits, Systems, Control, Signals (CSCS'13 and the 1st International Conference on Electronics and Electrical Engineering (ELEL '13), Valencia, Spania August, pp. 162-166, ISBN: 978-960-474-321-6, (2013).
- NI USB-6001/6002/6003 User Guide - National Instruments.*
- Software Matlab 2014b*
- Software MATLAB 2018a*

## Vectorial approach in smart grid directional protection using high speed microcontrollers

Mircea Risteiu<sup>a</sup>, Remus Dobra<sup>a\*</sup>, Constantin Hutanu<sup>a</sup>, Dragos Pasculescu<sup>b</sup>, Constantin Beiu<sup>c</sup>

<sup>a</sup>University "1 Decembrie 1918" Alba-Iulia, Gabriel Bethlen 5, 510009, Alba, Romania

<sup>b</sup>University of Petrosani, 20 Universității st., Petrosani 332006, Hunedoara, Romania

<sup>c</sup>INCDPM "Alexandru Darabont", 35A Blvd Ghencea, 6th county, Bucharest 062692, Romania

### Abstract

This research studies the directional protection that is a form of protection that utilizes measurements to determine the direction of the fault. Directional protection enables better discrimination of the faulty part of the network than with overcurrent protection. The direction in which the fault occurs is detected by measuring the direction of current flow, or in other words the phase displacement between the current and voltage. Directional phase protection equipment may be preferred to differential protection equipment to protect two parallel connected transformers, especially if the two busbars are quite far apart. The study proves the vectorial approach of the directional protection in three phase power networks using high speed microcontrollers.

**Keywords:** directional protection; smart grid; high speed microcontroller; computational protection.

### 1. Introduction

Directional elements respond to the phase shift between a polarizing quantity and an operate quantity. In figure 1 is presented the general circuit diagram of directional protection. In this diagram the faulted phase voltage,  $V$ , is the polarizing quantity, and the faulted phase current,  $I$ , is the operate quantity.

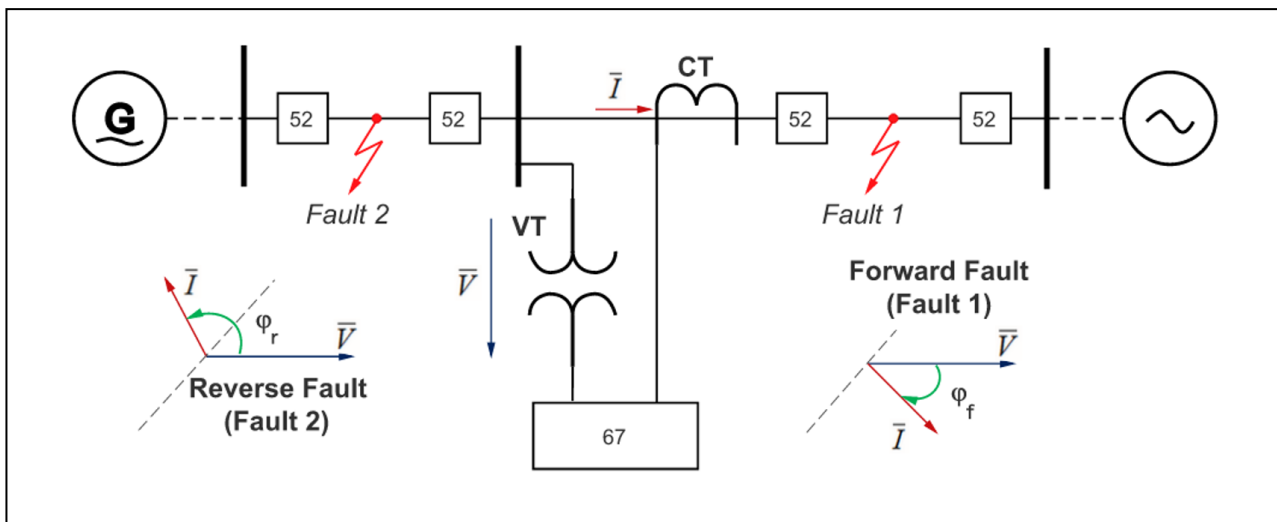


Fig. 1. Single line diagram for directional relay connection. The fault location, with best disconnecting decision by the breakers (pairs of two 52 devices), is done by the AC directional overcurrent relay (67).

\* Corresponding author. Tel.: 0258/811512

E-mail address: remusdobra@uab.ro.

Because lines are predominantly inductive,  $I$  lags  $V$  by the fault loop impedance angle,  $\phi_f$ , for forward line faults. For reverse faults on the adjacent line,  $I$  leads  $V$  by approximately 180 degrees minus the fault loop impedance angle,  $\phi_f$ . The options for selecting polarizing and operate signals vary and include voltage or current signals or phase.

Directional relays have a settable characteristic angle to take into account the transmission line angle. Usually, the operating region is  $\pm 90$  degrees from the characteristic angle. Variations of this basic directional technique include having a separate forward and reverse operation region for enhanced security (Chen W., et al., 2003).

## 2. Vectorial analysis of directional protection

The relay operational mode  $f(a)$  correspond to three possibilities: 1. Disable = Non-Directional; 2. Sup. = Directional Supervision; 3. Dir. = Total Directional. On each phase the relay measures the current " $I_x$ " and its displacement " $\phi_x$ " from the relevant phase-to-neutral voltage " $E_x$ ". The overcurrent element operates independently from the current direction (Radojevic Z., et al., 2000).

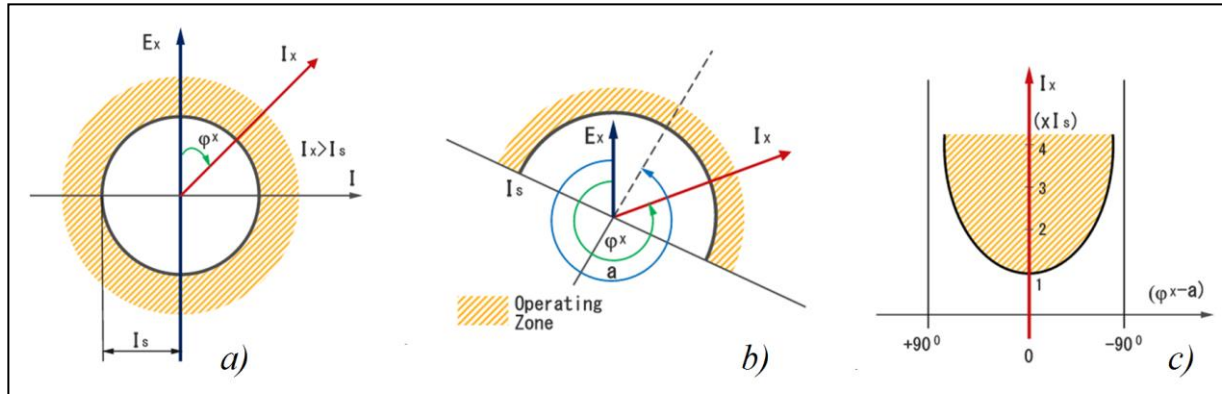


Fig. 2. Directional protection vectorial approach: a) The protection area is configured when directional relay characteristic function is disabled  $f(a) = \text{Disab.}$ ; b) Protected area when directional relay characteristic function is settled as  $f(a) = \text{Sup.}$ ; c) Both directions detection: directional relay characteristic function is settled  $f(a) = \text{Dir.}$

### 2.1. Non-directional mode

Different operation modes are possible according to the programming of the variable " $f(a)$ " from the relay software. The meaning of the main variables are:

- $I_s$  = Minimum operation current level.
- $a$  = Operation reference angle (phase  $x$ ;  $x = A, B, C$ ).
- $I_x$  = Measured input current (largest among the three phase currents  $I_A, I_B, I_C$ ).
- $\phi_x$  = Phase displacement of current " $I_x$ " from phase-to-neutral " $E_x$ " ( $X = A, B, C$ ).

### 2.2. Directional mode

The Overcurrent element only supervises the direction of the current and the operation conditions are:

- Input voltage above 1-2% of the rated input value.
- Input current above the set level:  $I_x > [I_s]$
- Phase displacement " $\phi_x$ " within  $\pm 90^\circ$  from the reference direction " $a$ ".

### 2.3. Total directional mode

Recommended reference angles for different applications:

- Measurement of resistive component of current (active power):  
Direct:  $a = 0^\circ$  - Reverse :  $a = 180^\circ$
- Directional phase fault detection:  
Direct:  $a = 300^\circ (60^\circ \text{ lag})$  - Reverse :  $a = 120^\circ$
- Measurement of inductive reactive component:  
Direct:  $a = 270^\circ (90^\circ \text{ lag})$  - Reverse :  $a = 90^\circ$
- Measurement of capacitive reactive component:  
Direct:  $a = 90^\circ (90^\circ \text{ lead})$  - Reverse:  $a = 270^\circ$



### 3. Directional protection programming

The configuration of the digital relay is done by connecting it and PC via an USB – RS485 cable. Based on dedicated software the relay was set up in terms of directional protection. The main screen of the software look likes the graphical interface presented in the next figure. After started MCom2, the relay can be connected by clicking the “On serial port”.

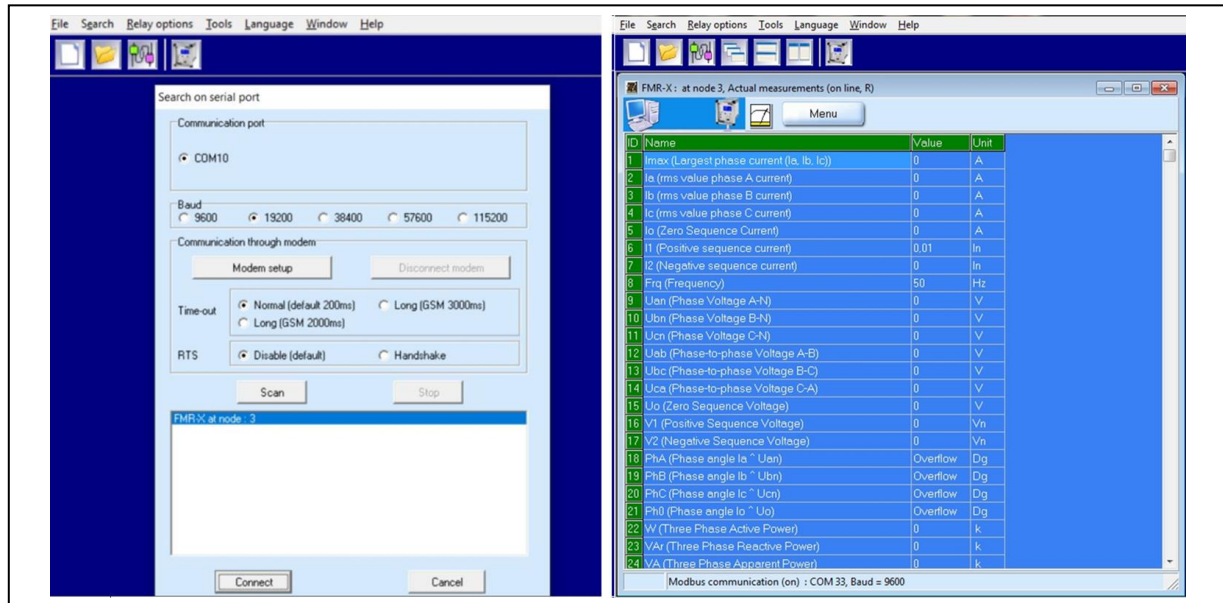


Fig. 3. The “Scan” option, must be used when we want to connect to the relay through a serial port (real or virtual). MCom2 can open more than one relay at the same time.

Directional overcurrent relays utilize the reference voltage phasor for estimating the direction of the fault (Valsan S., et al., 2007). This requires measurement of both current and voltage using specific sensors (current and voltage transformers). The information regarding the current is represented by  $I_{L1}$ ,  $I_{L2}$ ,  $I_{L3}$  and for the voltage measurement the digital relay uses  $V_{L1-0}$ ,  $V_{L2-0}$ ,  $V_{L3-0}$ .

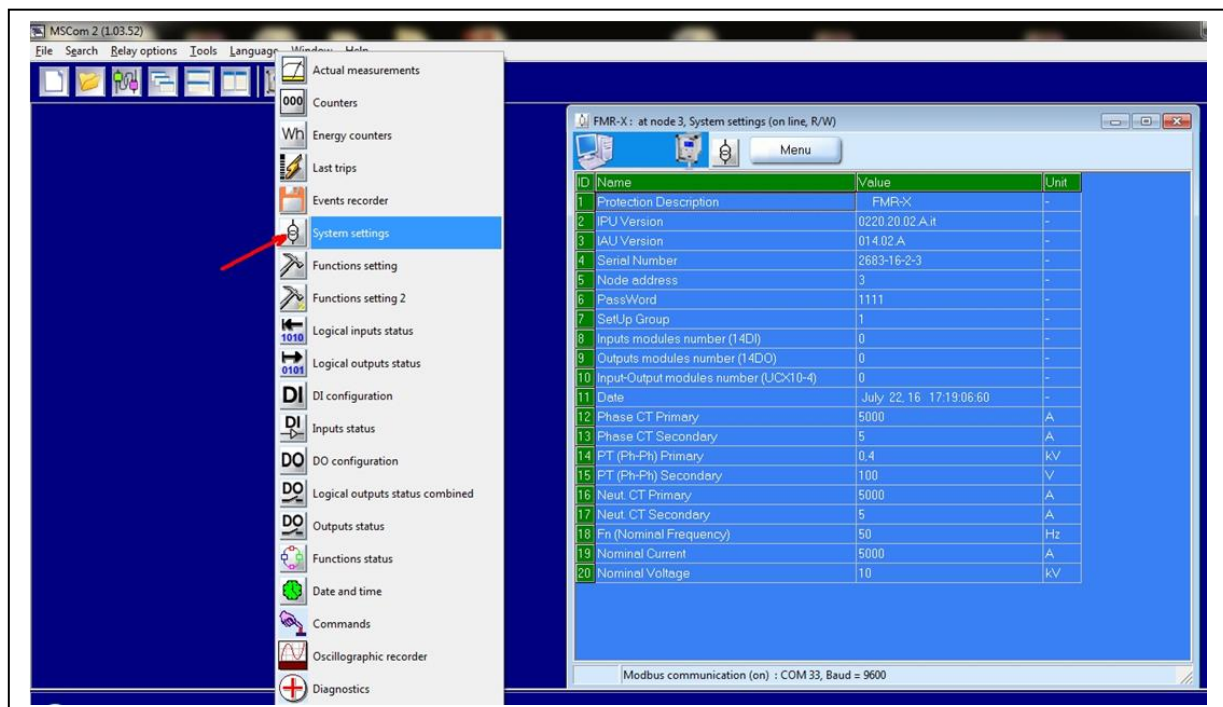


Fig. 4. Directional protection configuration from system settings

The directional relay was configured by entering in to the “Settings” option from relay software. From this window you can set up the main parameters of the equipment. Set up the rated current at 5000mA.



### 3.1. Non-directional mode relay programming

The relay based on high speed microcontroller will function when the AC input current exceeds a predetermined value on non-directional. By increasing the resistive load will cause a current higher than 500mA that was the trip level of the relay. It can be observed in figure 5 that only the amplitude of the current on second phase (Ib) is greater than the set-up trip level. It can be observed in figure 6 that the amplitude of the current on first phase (Ia) is greater than the set-up trip level. In this case also the phase displacement " $\phi_x$ " within  $\pm 90^\circ$  is greater than the reference direction "a".

Because the relay was programmed to work as non-directional protection the relay didn't trip. The overcurrent element operates independently from the current direction.

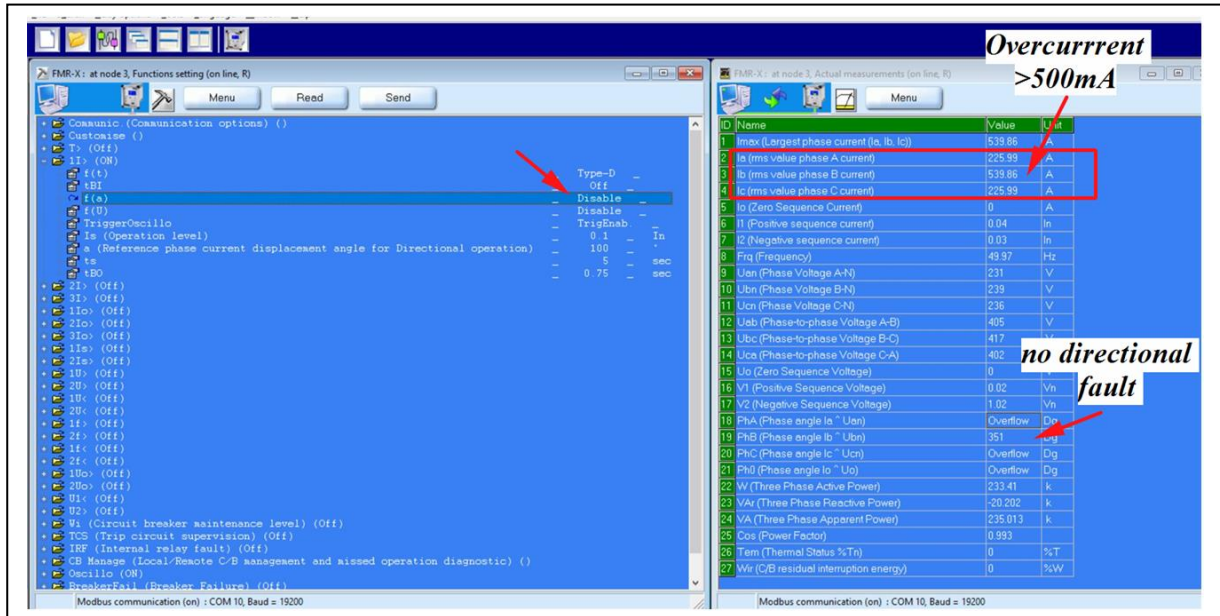


Fig. 5. Overcurrent fault (set-up directional relay as disable).

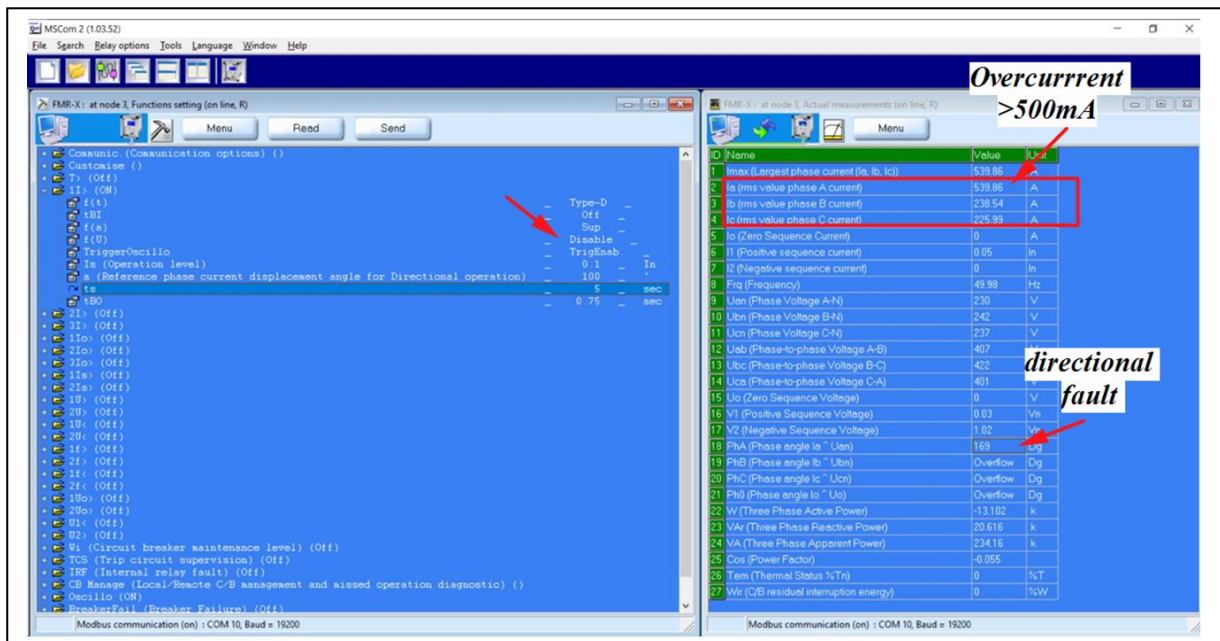


Fig. 6. Overcurrent and directional current fault (set-up directional relay as disable).

### 3.2. Directional mode relay programming

Set the II> to ON and the f(t) to Type-D. Select operation function f(a) as "Sup" and press OK. This will configure the directional relay to work in supervision mode, based on the characteristic described in next figure. Set the reference phase current displacement angle at 100 degrees.

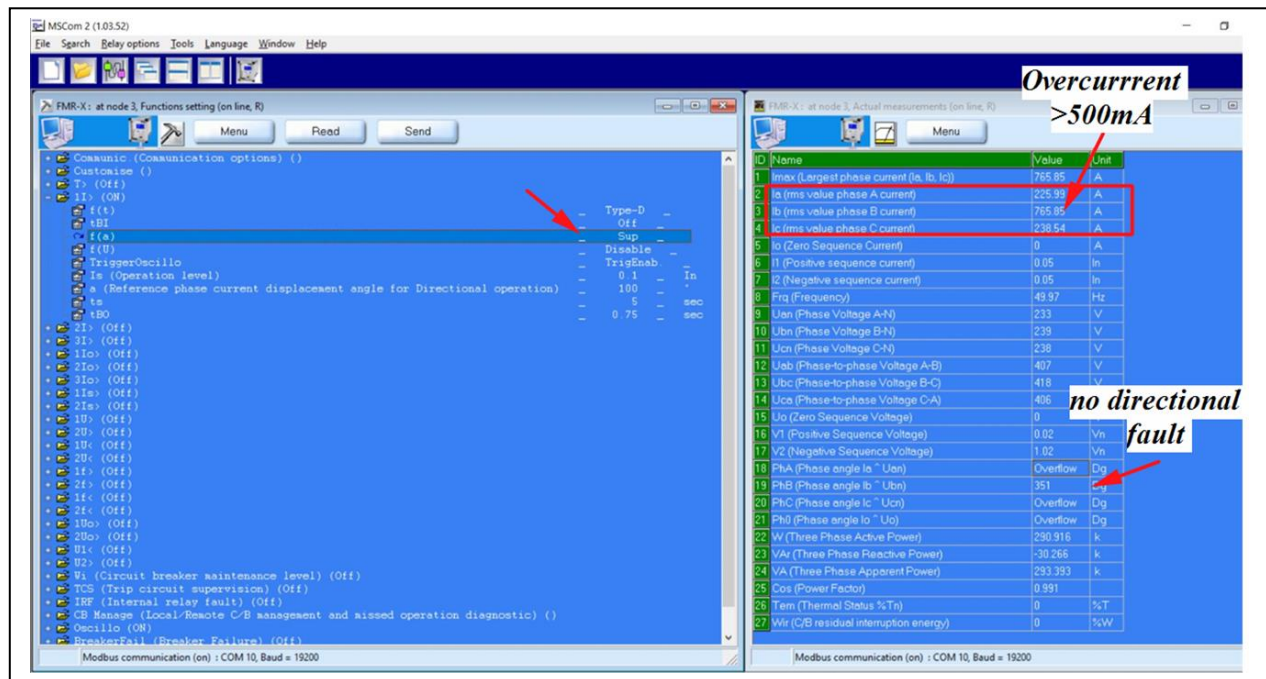


Fig. 7. Overcurrent fault (set-up directional relay as Sup).

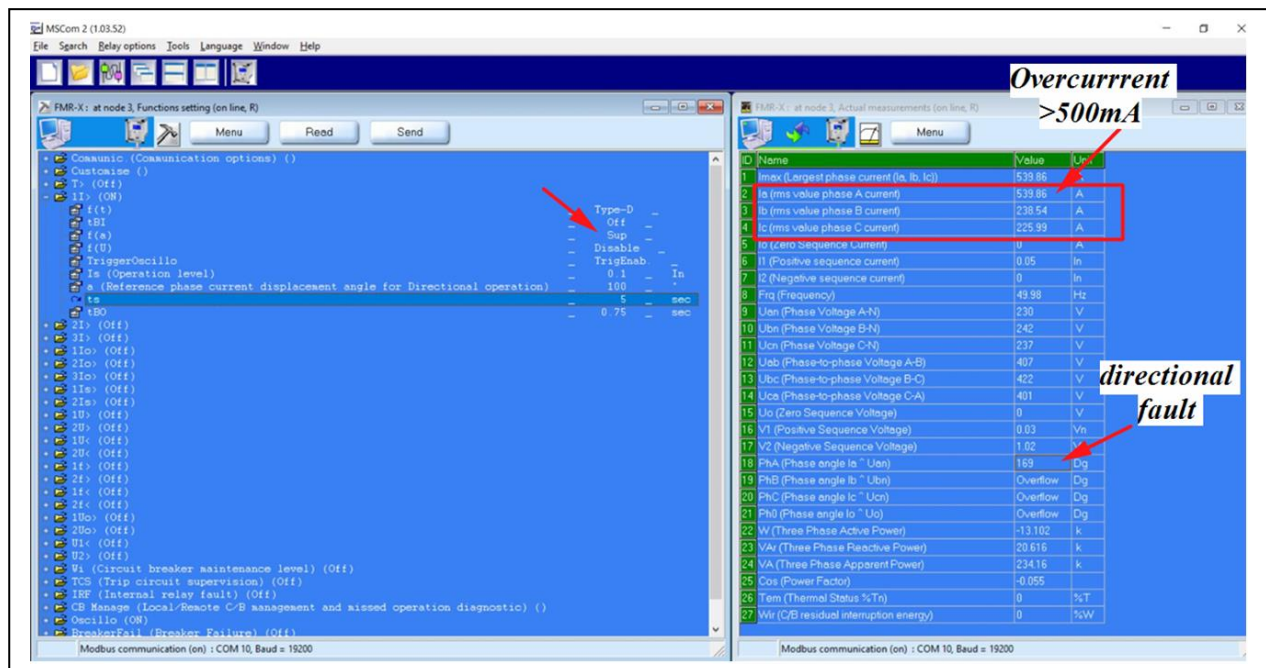


Fig. 8. Overcurrent and directional current fault (set-up directional relay as Sup)

Increasing the load current over the threshold and by simulating a directional fault will cause the relay to trip. By recording the current and voltages curves, as is presented in figure 9, we can observe the phase displacement in between current  $I_A$  (from phase 1) and  $U_{an}$ . In figure 9a the displacement occurred when we have reversed the direction of the current. In figure 9.b with normal flowing of current the  $I_b$  (on phase 2) and  $U_{an}$  there is no displacement.

When the angle in between the maximum current and the maximum voltage exceeds a set threshold, the directional relay trip and give the switching off command to the circuit breaker.



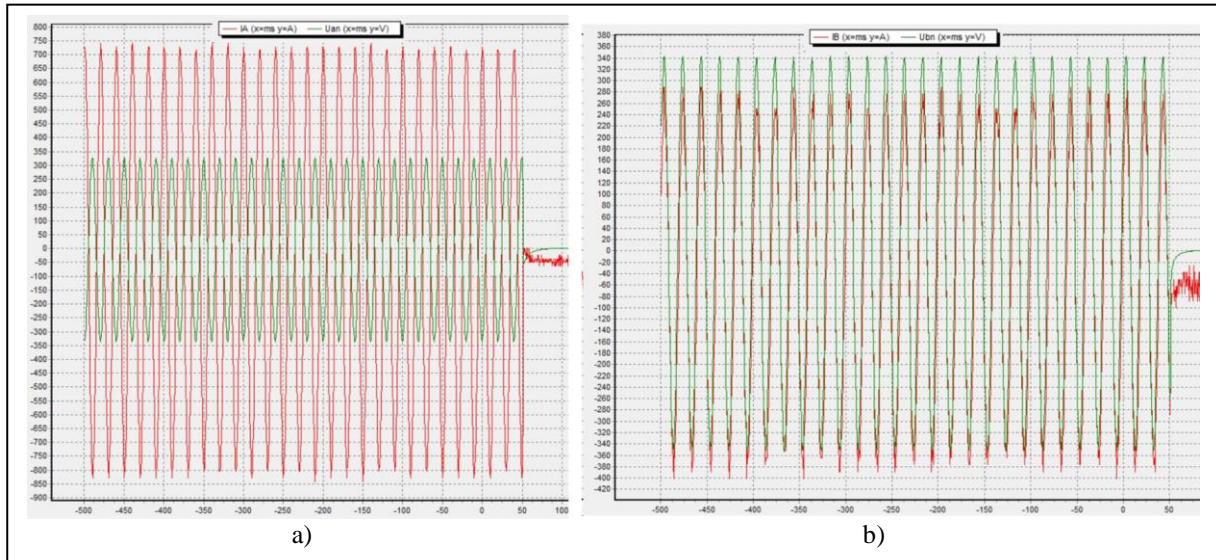


Fig. 9. Measured curves of line currents and voltages

#### 4. Conclusions

The proposed architecture for the future work is shown above. There is a need to separate the process levels than management level. The link between them is based by communication support.

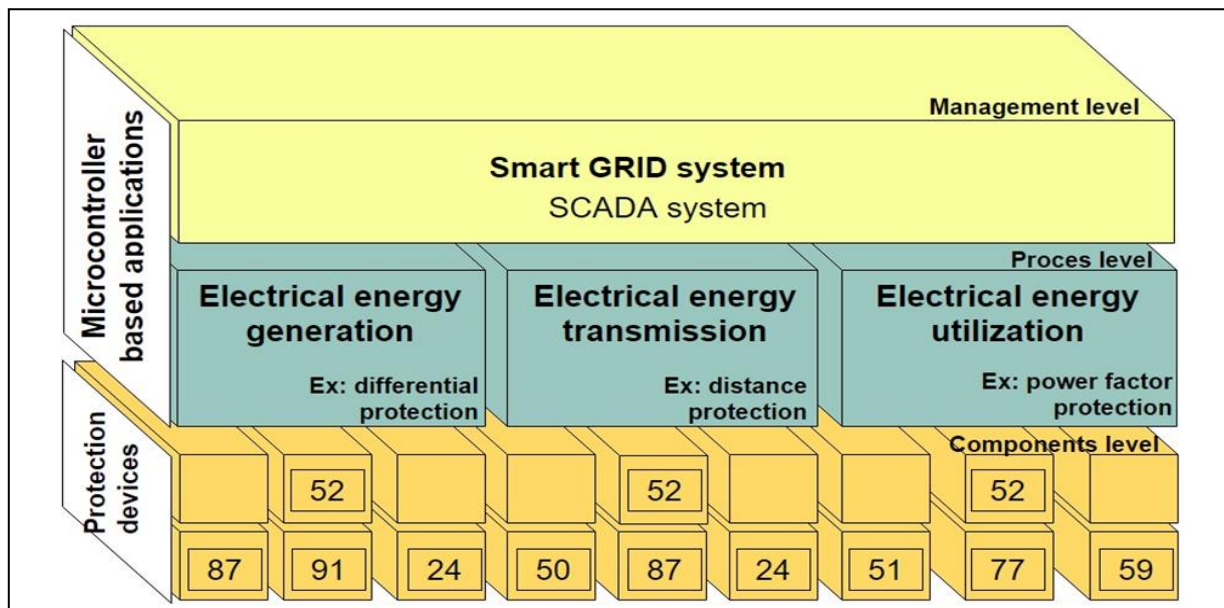


Fig. 10. Designed architecture of the directional protection integrated in high level processing

#### References

- Wei, C. et al., Study of wavelet-based ultra-high speed directional transmission line protection, *IEEE Transactions on Power Delivery* 18.4 1134-1139, (2003).
- Radojevic, Z. M., Terzija, V. V. and Djuric, N. B., Numerical algorithm for overhead lines arcing faults detection and distance and directional protection, *IEEE transactions on power delivery* 15.1 31-37, (2000).
- Valsan, S. P., and K. S. Swarup, Computationally efficient wavelet-transform-based digital directional protection for busbars, *IEEE Transactions on Power delivery* 22.3 1342-1350, (2007).

# Computational based method for smart differential protection of the electrical power networks

Remus Dobra<sup>a\*</sup>, Mircea Risteiu<sup>a</sup>, Florin Samoila<sup>a</sup>, Dragos Pasculescu<sup>b</sup>, Georgeta Buica<sup>c</sup>

<sup>a</sup>University "1 Decembrie 1918" Alba-Iulia, Gabriel Bethlen 5, 510009, Alba, Romania

<sup>b</sup>University of Petrosani, 20 Universității st., Petrosani 332006, Hunedoara, Romania

<sup>c</sup>INCDPM "Alexandru Darabont", 35A Blvd Ghencea, 6th county, Bucharest 062692, Romania

---

## Abstract

Differential relaying systems are used for most of electrical power network components, such as generators, transformers, stations buses and transmission lines. We will focus is this experiment on the transmission lines differential protection. In this method, the differential relay will compare the incoming phase currents of a network component to the outgoing phase currents of it. If these currents differ from each other as to the amplitude or phase angle or both more than allowed by the setting values of the relay, the relay will trip.

*Keywords:* differential protection; power transformer; synchronous generator; computational protection method.

---

## 1. Introduction

Electrical energy generated by various electrical power stations is gathered by a central electrical grid and then redistributed to various users based on real-time supply and demand characteristics. In electrical power system, the main functional requirement of a protection relay, for a protection relay to operate effectively, it must fulfill some major functions (Ziegler, 2011):

- Reliability: when a fault occurs, they should respond as quickly as possible, and in any circumstances.
- Selectivity: the protection system should respond only when a fault occurs, and it must only operate on the section that has experienced a fault to avoid unnecessary power.
- Sensitivity: the protection system should be highly sensitive so that it can be relied on to provide the required detection.
- Speed: the protection system equipment must operate at the required speed. It should not delay so as to give time for system equipment to get destroyed. It should also not be too fast to cause undesired operation.

The transmission line protection based on the microcontroller technology use the electric power system currents and voltages provided through several conversions – the instrument transformers and secondary circuits in the substation, as well as the analog inputs and internal processing in the device. The secondary currents and voltages that are applied to the distance protection relay are filtered and processed in the analog input module and provide instantaneous sampled values to the internal digital data bus of the transmission line protection (Loko, 2010).

## 2. Smart differential protection method

Differential protection can be used to detect internal faults in the windings of generators, including ground faults, short circuits and open circuits. Transformer protection methods that use its terminal behavior are based on differential protection is considered as a most widely used technique to perform the protection function. Potential causes of faults are damaged insulation due to aging, overheating, over-voltage and mechanical damage (Gguzman, 2001).

---

\* Corresponding author. Tel.: 0258/811512  
E-mail address: remusdobra@uab.ro.

There are two current transformers: one CT is connected to the line side of the generator and the other is connected to the neutral side of the generator in each phase. The characteristics of all current transformers installed against each phase must be matched. If there is any major mismatch in the current transformer's characteristics of both sides of the generator, there may be a high chance of malfunctioning of the differential relay during the fault external to the stator winding and maybe during the normal operating conditions of the generator.

### 2.1. Power transformer differential protection

Differential protection scheme can be used to protect both the primary and secondary windings of a three-phase transformer. The fundamental operating principle of transformer differential protection is based on comparison of the transformer primary and secondary winding currents, as is presented in figure 1.

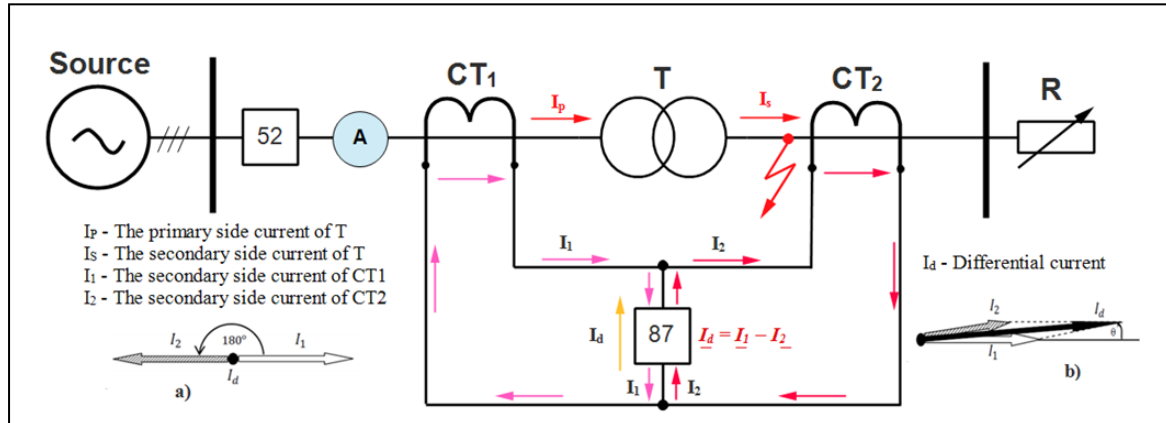


Fig. 1. Single line diagram of differential protection for power transformer (87- differential protective relay compares currents differences at both primary and secondary windings of a three-phase transformer through CT1 and CT2 systems, then, based by differences value sends commands the breakers-52 to insulate the fault)

If there is no internal fault occurring within the power transformer protected zone, the currents  $I_1$  and  $I_2$  are assumed equal in magnitude and opposite in direction. That means the differential current  $I_d = 0$  as presented in figure 1.a. If there is any fault in the power transformer protected zone, the currents  $I_1$  and  $I_2$  are no longer equal in magnitude and opposite in direction. That means the differential current  $I_d$  has a significant value as shown in figure 1.b.

The amount of current  $I_d = I_d \angle \theta$  induces the differential relay (87) to operate in order to send a trip signal to the circuit breakers (52) to isolate the transformer.

### 2.2. Synchronous generator differential protection

In generators with single windings per phase, the differential protection is similar to the transformer protection.

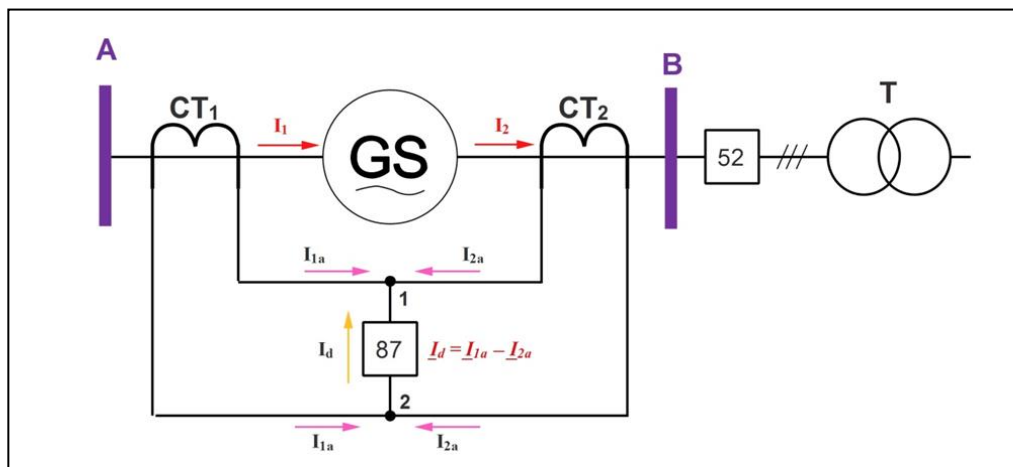


Fig. 2. Single line diagram for differential generator protection (87- differential protective relay compares currents differences at both ends of the generator through CT1 and CT2 systems, then, based by differences value sends commands the breakers-52 to insulate the fault).

### 2.3. Method description

In figure 3 is presented the operating characteristic of the differential current relay that correlates the currents on either side of the protected transmission line. The operation of the differential relay is based on the comparison of the currents on either side of the protected area. The programmable levels must be done heaving as reference the point P.

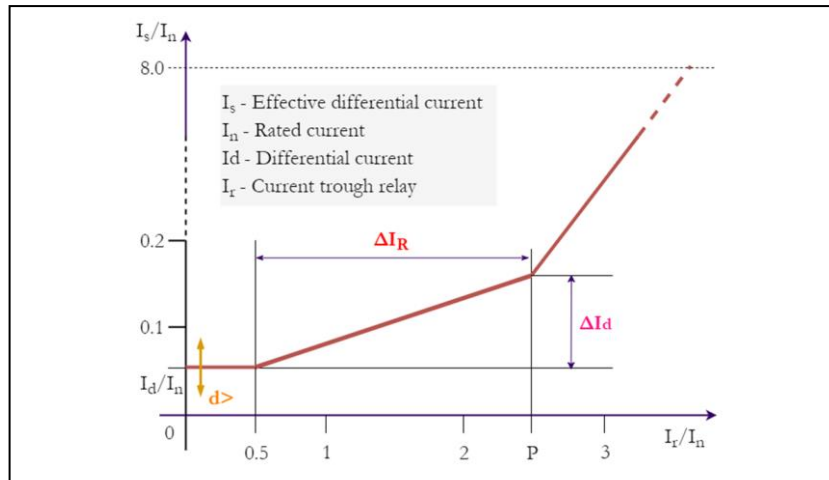


Fig. 3. Operating characteristic of the smart differential protection

A numerical differential protection has two typical slopes, based on which the relay will trip if the magnitude of the differential current is more than a fixed percentage of the restraining current. A dual-slope differential characteristic increases security for high-current external faults by applying greater restraint for greater currents to accommodate CT saturation errors, while allowing more sensitive operation for low-current internal faults.

### 3. Computational differential protection

This technique involves the comparison of the currents of each phase at each line terminal. A communication path is therefore an essential requirement of any such scheme. The basic operating principle of differential protection is to calculate the difference between the currents entering and leaving a protected zone. The protection operates when this difference exceeds a set threshold (Taalab et al., 2007).

In many practical situations the generator neutral is often grounded through a distribution transformer. This energizes a relay which operates the generator main and field breakers when a ground fault occurs in the generator or transformer. The ground fault is usually limited to about 10A by the distribution transformer or a resistor, although an inductor has some advantages. The field circuit of the generator must be opened when the differential protection operates in order to avoid the machine feeding the fault (Tripathy et al., 2010).

When loss of excitation occurs, reactive power (Q) flows into the machine, and if the system is able to supply this, the machine will operate as an induction generator, still supplying power to the network. The generator output will oscillate slightly as it attempts to lock into synchronism. Relays are connected to isolate the machine when a loss of field occurs, which can be readily detected by a reactance relay.

In power transformers the current-magnitude differences are corrected by adjusting the turns ratio of the current transformers to account for the voltage ratio at the transformer terminals. In a differential scheme the phase of the secondary currents in the pilot wires must also be accounted for with star-delta transformers (Yang et al., 2003).

#### 3.1. Software description

To calculate differential current between line ends it is necessary that the current samples from each end are taken at the same moment in time. This can be achieved by the continuous calculation of the propagation delay between line ends. The line parameters Z contain the R, L, C components. At the extremities of the zone to be protected, the currents are continuously compared and balanced by suitable relays. Provided that the currents flowing into and out of the zone are equal in magnitude and phase, no relay operation will occur. If, however, an internal fault (inside the protected zone) occurs, this balance will be disturbed, and the relay will operate.

If the current value of the supply voltage is less than 20% of the rated value; if the supply voltage is above the threshold of 20% reliable function, the system will generate a unique identifier numeric specific to the equipment. In this figure for differential protection is used the microcontroller relay. In order to give the switching off command to the circuit breaker the numerical differential relay has for output relays available. The relays are normally deenergized and are user programmable.



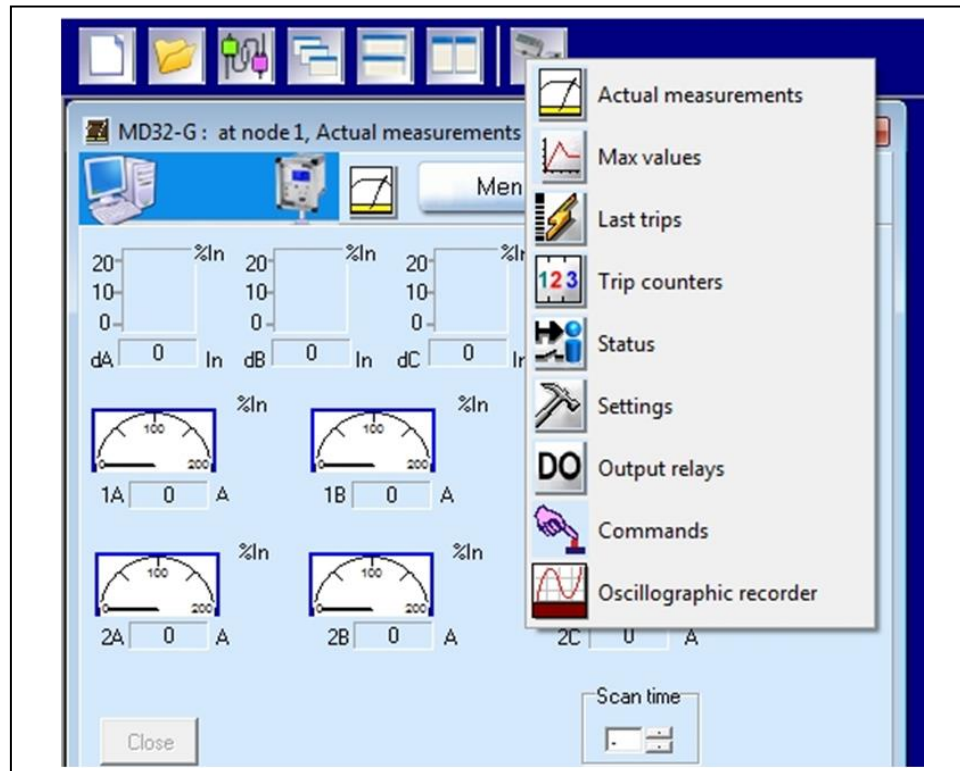


Fig. 4. Main window of the differential protection software

Using the graphical interface of the programming differential software from figure 5a the user can set up the trip values of the relay.

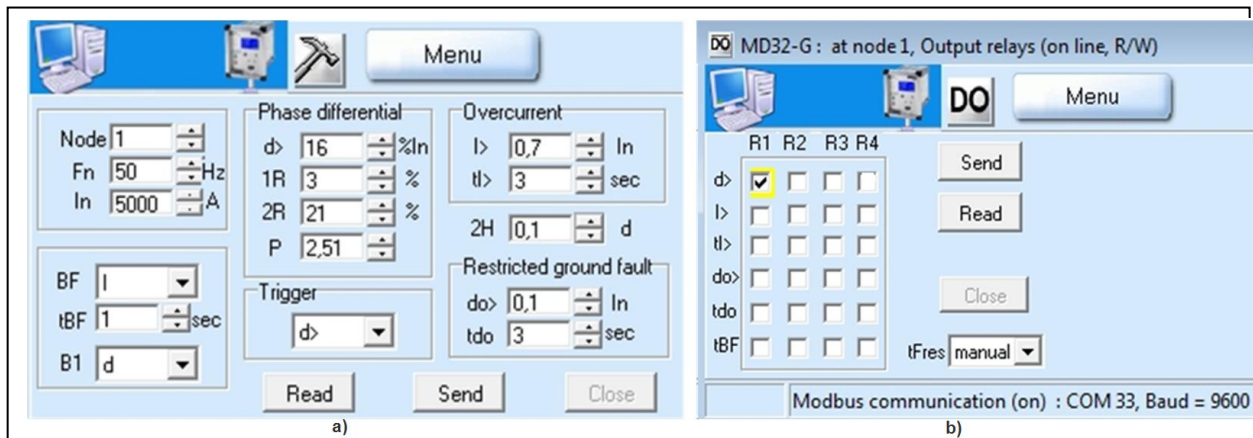


Fig. 5. Differential relay trip programming: a) main window, b) set up the differential output relay

The principle of operation of differential protection is similar to the differential systems for protecting generators and transformers, but the relays have different settings because the breakers at the ends of the line are more widely separated. For output relays are available (R1, R2, R3, R4). The relays R1, R2, R3, R4 are normally de-energized (energized on trip): these output relays are user programmable and any of them can be associated to any of the smart differential relay functions. For the function  $d>$  both instantaneous and time delayed elements are provided. The reset after tripping of the relays (when the tripping cause has been cleared) can be programmable as Manual or Automatic (Variable  $RR=Man/Aut$ ).

Based on this protection software we can select distinct types of parameters, described in the table below. For differential protection the selected variable will be  $d>$ .



Table 1. Smart differential protection variable setup

Variable	Default	Relay parameter description
Fn	50	Rated primary current of current transformers
In	500	Rated primary current of current transformers
d>	0.15	Basic minimum pick-up level of low set phase differential element
I>	5.00	Minimum pick-up level of over-current element
tl>	3.00	Time delay of over-current element
do>	0.1	Minimum pick-up level of Earth Fault element
tdo	500	Time delay of Earth Fault element
TGR	d>	Trigger for oscillography records is internal (TRG=d>, I>, do>)

The differential relay was programmed to trip at a 6% differential current in the protected area. In normal conditions in the actual measurements software interface the three phase currents should be equal to zero. On phase L3 (see differential current dC) was created a fault (just before the relay trip 0.053%)

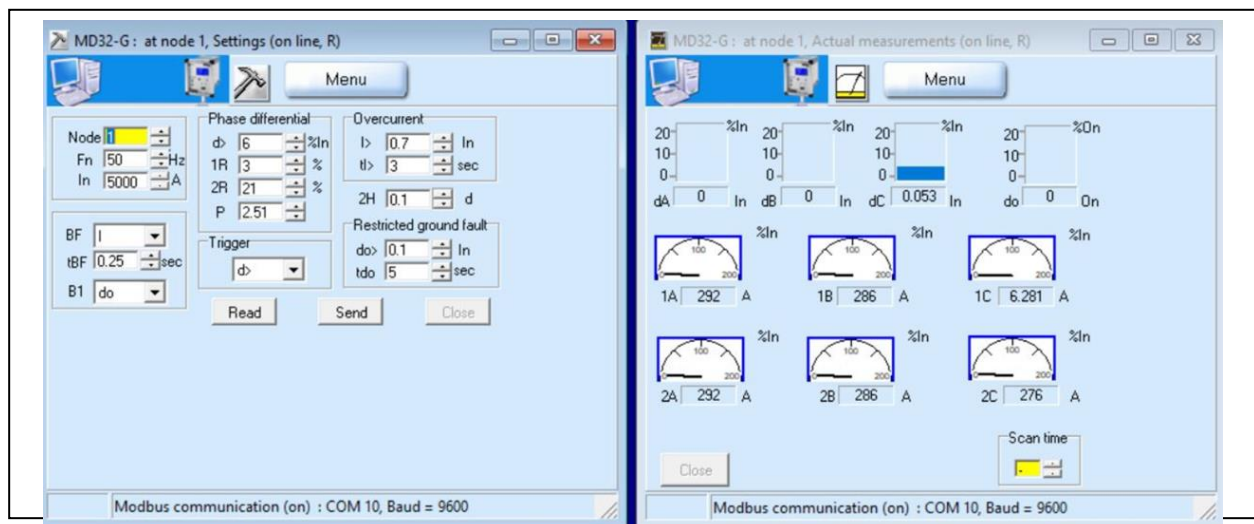


Fig. 6. Measurements recorded based on deferent loads (with differential fault on phase 3)

### 3.2. Recorded curves using digital differential protection

The form of differential protection using only one set of relays is not suitable for long overhead lines since the ends of a line are too far apart to be able to interconnect the CT secondaries satisfactorily.

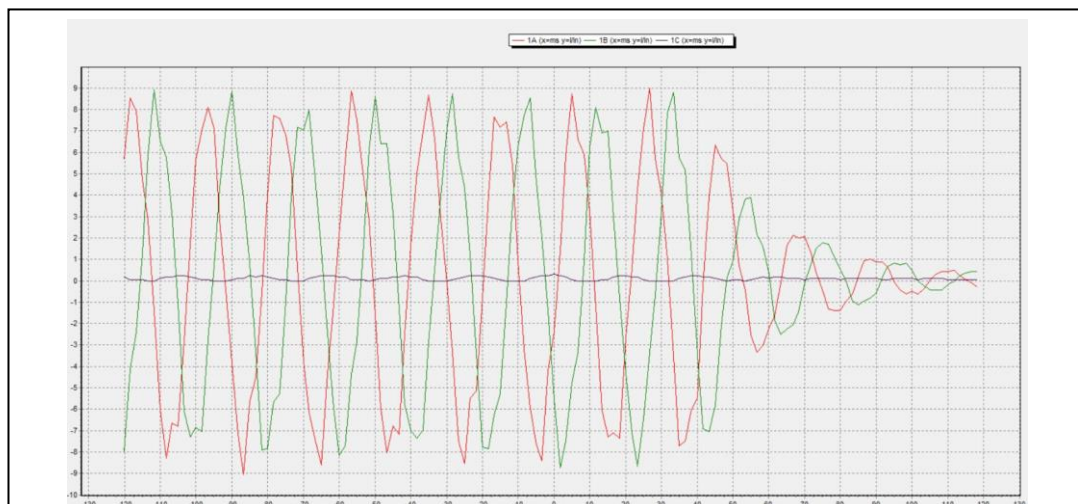


Fig.7. Measured currents on the input differential relay (1A, 1B, 1C).

It is therefore necessary to install a set of relays at each end of the circuit and interconnect them by some suitable communication link. Numerical differential protection (indicates that there is an interconnecting channel between the ends of the lines through which information can be transmitted) is an adaptation of the principles of differential protection. In figure 8 the register was obtained by making a differential fault by short-circuiting the current transformer from the output relay (see figure 1 – relay CT2).

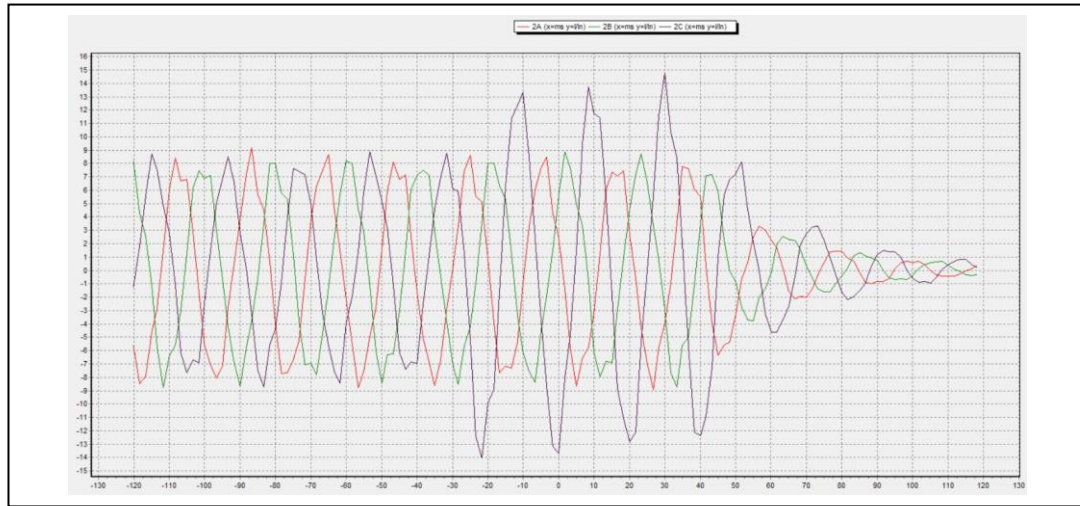


Fig. 8. Measured currents on the input differential relay (2A, 2B, 2C).

The connection of the protection device to the current transformers must be done in such a way that comparison of the currents can be carried out with respect to r.m.s. value and phase - angle. Protection schemes of transformers with vector groups different from 0 ° additionally require intermediate transformers to correct the differences in phase - angle between the HV and LV sides.

With three - winding transformers all windings have to be included in the differential protection scheme. With transformers having vector group YNynd, which are not grounded permanently, intermediate transformers likewise have to be planned, in order to ensure selectivity and avoid malfunction in the case of single - phase short - circuits by measuring the partial short - circuit current through the neutral.

#### 4. Conclusions

With shown and proved results, the implemented device runs differential protection and creates objects to a higher-level processing. By using a transmission line, generator and transformer simulator with real current transformers, the students create lines short-circuit scenarios, and see different reactions of the differential relay from the selectivity criteria point of view.

#### References

- Guzman, A., A current-based solution for transformer differential protection. I. *Problem statement. IEEE Transactions on power delivery*, 16.4: 485-491, (2001).
- Loko, A. Z., Bugaje, A. I., Bature, A. A., Automatic method of protecting transformer using PIC microcontroller as an alternative to the fuse protection technique, *International Journal of Technical Research and Applications*, e-ISSN: 2320-8163, pp 23-27, (2010)
- Taalab, Abdel-Maksoud I., Hatem A. Darwish, and Eman S. Ahmed, Performance of power differential relay with adaptive setting for line protection, *IEEE transactions on power delivery* 22.1 pp50-58, (2007).
- Tripathy, M., Rudra, P. M., and Verma H. K., Power transformer differential protection based on optimal probabilistic neural network, *IEEE transactions on power Delivery* 25.1 102-112, (2010).
- Yang, B., Lee, F. C., and Concannon, M., Over current protection methods for LLC resonant converter, *Applied Power Electronics Conference and Exposition*, Eighteenth Annual IEEE. Vol. 2. IEEE, (2003).
- Ziegler, G., *Numerical distance protection: principles and applications*. John Wiley & Sons, (2011).

# The blockchain as a backbone of GDPR compliant frameworks

Peyo Hristov<sup>a\*</sup>, W. Dimitrov<sup>a</sup>

<sup>a</sup>University of Library Studies and Information Technologies, "Tzarigradsko shose" Str.119, Sofia 1784, Bulgaria

---

## Abstract

General data protection regulation (GDPR) is applied since 25 May 2018. It is designed to harmonize data privacy laws in European Union. It clearly defines what personal data is and identifies involved objects as Controller, Processor and Data subject. Although it focuses over the procedures in the organizations that have contact with personal data, it raises technological challenges about data storage, data processing, access control, identity management, system resilience, cybersecurity, post security breach measures, transactions traceability. We offer a new conceptual model with a trust management technology between controllers and data processors, which is based on the capabilities of the DLT. It can be useful in synthesizing software architectures, managing change due to the implementation of GDPR, ePrivacy, Policy Directive, and another forthcoming EU legislation. The article aims to present where the blockchain implementation can be helpful for the GDPR compliant operations. It doesn't cover the GDPR or blockchain in deep technical details, but just points out the important aspects where the DLT solution could be applicable. The paper is structured as follows: Section 1 introduces the paper. Section 2 describes the methodology used in this article. Section 3 introduces the GDPR and points out with short descriptions the key principles of the regulation. Section 4 covers brief explanation what blockchain is with examples from the Bitcoin implementation. Terms like transaction, transactions integrity, block, consensus are described here. Permissioned and permissionless blockchain implementations with their basic difference in the level of trust. Section 5 defines the main intersection points between GDPR compliance and the blockchain. Section 6 presents the Hyperledger fabric blockchain framework founded by Open Linux Foundation and IBM. The section focuses over the unique Hyperledger fabric abilities, which leads to increased confidentiality, transaction speed, traceability, access control, identity management, endorsement policies and smart contracts applications. Section 7 shows related research in this area. In conclusion the study reveals the biggest challenge in the blockchain application in the GDPR compliant frameworks.

**Keywords:** blockchain; confidentiality; GDPR; Hyperledger Fabric.

---

## 1. Introduction

General data protection regulation (GDPR) is applied since 25 May 2018. It is designed to harmonize data privacy laws in European Union. It clearly defines what personal data is and identifies involved objects as Controller, Processor and Data subject. Although it focuses over the procedures in the organizations that have contact with personal data, it raises technological challenges about data storage, data processing, access control, identity management, system resilience, cybersecurity, post security breach measures, transactions traceability. The blockchain became very popular since the end of 2017, because of the Bitcoin's price. But the blockchain as an implementation of the distributed ledger technology (DLT), has unique combination of some features like: traceability, transactions non-repudiation, very strong cryptographic nature, decentralization - which drew the attention of this study. In addition, smart contracts empower the blockchain with ability to automate transaction processing with programmed rules. The article aims to present where the blockchain implementation can be helpful for the GDPR compliant operations. It doesn't cover the GDPR or blockchain in deep technical details, but just points out the important aspects where the DLT solution could be applicable.

In this paper we offer a conceptual toolbox that solves three major problems:

- Strengthening the possibilities for complying with the principles of data processing and transmission and fulfilling accountability requirements;
- Operational mutual control over compliance with GDPR requirements in groups of related organizations;
- Provide opportunities for minimal impact of GDPR compliance on business continuity.

---

\* Corresponding author. Tel.: +359-889-633-674  
E-mail address: p.t.hristov@unibit.bg.

## **2. Methodology**

The methodology of this article is based on a review over the essence of the GDPR and especially on the parts, where more complicated technical solution is needed. Bitcoin's blockchain is selected for the blockchain's overview, because it is quite simple and shows the most important aspects of the blockchain - transactions integrity, blocks sequence, consensus etc. Hyperledger Fabric official documentation and author's experience in Hyperledger Fabric deployment and chaincode applications are used for explanation about multiple organizations (MSP) channels confidentiality and endorsement procedures, together with chaincode smart contracts. In the conclusion part the immutability vs. "Right to be forgotten" issue is raised as the main challenge in the GDPR and blockchain cooperation.

## **3. What a GDPR stands for?**

GDPR is an abbreviation of General Data Protection Regulation. It replaces DPD (Data Protection Directive) 95/46/EC. It is designed to harmonize data privacy laws in EU to protect and empower all EU citizens data privacy and to reshape the way organizations across the region approach data privacy. In fact, GDPR is the most important change in data privacy regulation in 20 years (EU GDPR portal, 2018).

GDPR clearly identifies the following objects (ICO, 2018):

- Controller - determines the purposes and means of processing personal data.
- Processor - responsible for processing personal data on behalf of a controller.
- Data subject - a physical person. The personal data owner.

Definition of "personal data" and "processing" are also straightforward:

"personal data" means any information relating to an identified or identifiable natural person ('data subject'); an identifiable natural person is one who can be identified, directly or indirectly, in particular by reference to an identifier such as a name, an identification number, location data, an online identifier or to one or more factors specific to the physical, physiological, genetic, mental, economic, cultural or social identity of that natural person;" (Concil of the European Union, 2016)

"processing" means any operation or set of operations which is performed on personal data or on sets of personal data, whether or not by automated means, such as collection, recording, organization, structuring, storage, adaptation or alteration, retrieval, consultation, use, disclosure by transmission, dissemination or otherwise making available, alignment or combination, restriction, erasure or destruction;"(Concil of the European Union, 2016)

At a first glance, it seems that the controller is free from GDPR obligations, but this assumption is far away from the truth - the GDPR places further obligations on you to ensure your contracts with processors comply with the GDPR ((ICO, 2018)).

From what has been said above is obvious, that the huge part of the business is affected by this regulation. Gartner clearly says, that organizations are unprepared for GDPR (Gartner,2017). Unfortunately, Forrester also predicts, that 80% of the companies affected by the regulation, will not fully comply to it until 25th of May 2018 (Forrester, 2017).

The goal of this article is not to reveal in deep GDPR, but for completeness we should mention the basic principles of the regulation - they are its heart:

- Lawfulness, fairness and transparency
- Purpose limitation
- Data minimization
- Accuracy
- Storage limitation
- Integrity and confidentiality (security)
- Accountability

It is maybe not accidentally, that "Lawfulness, fairness and transparency" is placed on first. Staying away from the legal aspects of this principle, the fairness and transparency are the really important pieces here from the present article's point of view. However, we should remember that they are very close linked together, and violation of any of three fails the whole. Fairness could be violated for example, when the controller obtains personal data but the data subject is misled or deceived in this process. Hence, this clarifies the transparency requirement. The data controller must provide a clean and open (transparent) way, to can data subject approve the lawfulness and fairness pieces of the principle.

Purpose limitation. Purposes for collecting personal data should be clear. The organization is obligated to specify these purposes in a clear way in the privacy information to the individuals. The personal data could not be used for other purposes, except in the cases they are compatible with the original or the organization have a new consent from the customer.

Accuracy is another key topic in this research. According to the regulation, personal data shall be accurate and, where necessary, kept up to date; every reasonable step must be taken to ensure that personal data that are inaccurate, having regard to the purposes for which they are processed, are erased or rectified without delay. (Concil of the European Union, 2016)

Storage limitation says, that you must not keep personal data than you need it. After that you must take measures to erase or anonymize it. Not only at controller's side, but also at all processors side. And of course, the organization must be able to prove that.

Integrity and confidentiality looks as the most related to the cybersecurity. But this principle isn't limited only to the way organization store and transfer data - organizational security is the real keystone here. It covers also how the data can be altered, accessed, deleted etc. Have the accessing entity enough permissions to do so and what access level exactly have and of course - who grants these rights. Have the organization working solution how to recover data after an accident and how will ensure its integrity between the parties. Security awareness education of the organization's staff takes a place here. The right risk assessment of the personal data stored, both with used hardware equipment, also have important role in this principle.

And at the end, here comes the Accountability principle. In short, the organization should be able to prove its GDPR compliance. Most noticeable in the scope of this article is the ability to detect, record and report security breaches. Data protection by design and more importantly - by default, is mandatory requirement here.

#### 4. The blockchain

"A 'blockchain' is a particular type of data structure used in some distributed ledgers which stores and transmits data in packages called 'blocks' that are connected to each other in a digital 'chain'. Blockchains employ cryptographic and algorithmic methods to record and synchronize data across a network in an immutable manner." (Natarajan et al., 2017)

The blockchain main concept for linked blocks is more clearly illustrated on Figure 1.

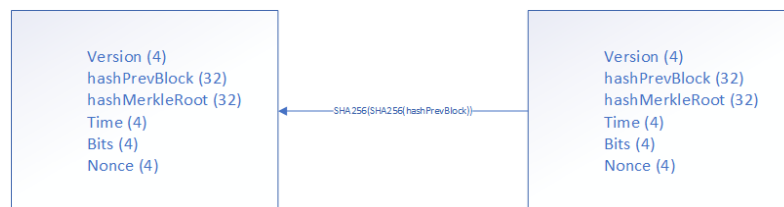


Fig. 1 - Bitcoin's linked blocks headers.

hashPrevBlock - the hash of the previous block = (SHA256(SHA256(block header)))

hashMerkleRoot - the root hash of the merkle tree of all transactions in the block

Inside every block, are stored the transactions. The transaction in a Bitcoin's blockchain means a ledger for transferred amount of cryptocurrency from one owner to another, as shown on Figure 2.

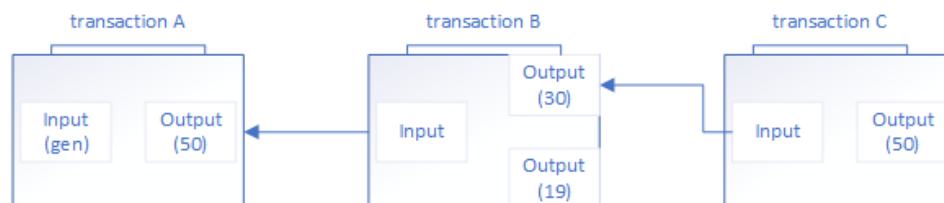


Fig. 2 - Transactions stored inside a Bitcoin's block. In transaction A, the owner initially owns 50 units. In transaction B, he sends 30 units to another owner in transaction C and keeps 19 units for himself. Note, one unit is lost for the transaction fee.

"Blockchains are distributed digital ledgers of cryptographically signed transactions that are grouped into blocks. Each block is cryptographically linked to the previous one after validation and undergoing a consensus decision. As new blocks are added, older blocks become more difficult to modify. New blocks are replicated across all copies of the ledger within the network, and any conflicts are resolved automatically using established rules." (Yaga et al., 2018)

As seen from Figure 1, every block (except the first block also called "genesis block") keeps the hash of the previous block header in hashPrevBlock header field. Noticeable here is hashMerkleRoot field, which keeps the integrity of the included in the block transactions. Hence hashPrevBlock relations between the blocks in the chain, protects the whole chain integrity. If an attacker modifies a transaction in earlier block, he will modify the hashMerkleRoot value which will affect attacked block header hash. After that, the next block's hashPrevBlock value will be wrong, so the attacker must alter all subsequent blocks in order to keep the blockchain's integrity. And here comes where the "Distributed" word in Distributed Ledger Technology takes place. Every new block or sequence of blocks (fork) should be successfully tested against some specific rules (for example longer fork wins) from a given amount of DLT nodes in order to be accepted. Moreover, every transaction must evaluate to true in a given application (also known as "smart contract") to become a part of a block. The whole process is called consensus.

According to the Hyperledger fabric documentation, consensus is a broader term overarching the entire transactional flow, which serves to generate an agreement on the order and to confirm the correctness of the set of transactions constituting a block. (Hyperledger, 2018)



The consensus is crucial part of the system based on DLT. That's because of the nature of different usage purposes. In the permissionless systems, there is an absence of trust. The consensus is based in a form of byzantine fault tolerance algorithm, based on "proof of work" which is based of huge waste of energy (Hern, 2017) and slows down the block acceptance speed and more practically important - the transaction speed.

But the enterprises or governments rare operates in environment with such lack of trust. They operate among a set of identified and known nodes. So, they operate in an environment with a certain degree of trust. Hence the permissioned model is more suitable for them and more simple and fast consensus protocols could be applied like crash fault tolerant and byzantine fault tolerant based. The DLT based on the permissioned consensus is in the focus of this article.

## 5. The points of interest

In a previous section, we take a brief look over the important concepts in GDPR. Specific organizational and technical measures should be taken in order to be compliant.

**Transparency** for example, is needed to the organization to can proof how the data is used. There should be a non-repudiation way to can organization proof who accessed this data.

**Accuracy** is another example. The data should be in-time altered or even erased if needed and all participating parties should receive the altered data or delete it.

**Storage limitation** is also complicated technical requirement. It also dictates, that data should be anonymized and deleted when no longer needed or at individual request. Also, reidentification risk should be taken in mind. Direct identifiers must be avoided - **"data that can be used to identify a person without additional information or with cross-linking through other information that is in the public domain."** (ISO, 2008). Hence, the pseudonomization of personal data is a mandatory requirement.

**Confidentiality and data integrity** - how the data can be altered, accessed, deleted etc. Have the accessing entity enough permissions to do so and what access level exactly have and of course - who grants these rights.

**Every data modification or access should be accounted.** Data protection by design and more importantly - by default, is really required.

The requirements are so complex and of course single solution is hard to be found. At first glance, the DLT fits here. The blockchain implementation has its intrinsic abilities: data integrity, non-repudiation, data distribution. But at a second glance, some great issues can be found: lack of confidentiality, lack of access control, impossibility data to be forgotten etc. Yes, that is true. But only for the public (Zheng et al., 2017) blockchains like Bitcoin, Ethereum, Iota etc.

## 6. Hyperledger fabric

Hyperledger fabric framework (Hyperledger fabric, 2018) is one of the projects hosted by Linux Foundation together with IBM. With its modular architecture, it helps developers to create a blockchain based system for data distribution and control but avoiding permissionless blockchains drawbacks especially in the part of data confidentiality and access control. Thanks to its new architecture called execute-order-validate, the goals as flexibility, performance and confidentiality can be achieved in very convenient way.

Confidentiality comes together with a concept of channels. Channels are the virtual "way" to separate data available to organizations. Only allowed nodes could join the channel and it is nearly impossible rogue node to join in and eavesdrops the data in it. Node could be added in the channel only from an entity with the permission to do so. One node could join several channels. In the Figure 3 Organization 1 has two nodes in channel 1, but organization 2 has only one. However, Organization 1 peer 1 is joined in two channels channel 1 and channel 2, but channel 2 includes Organization 3 also.

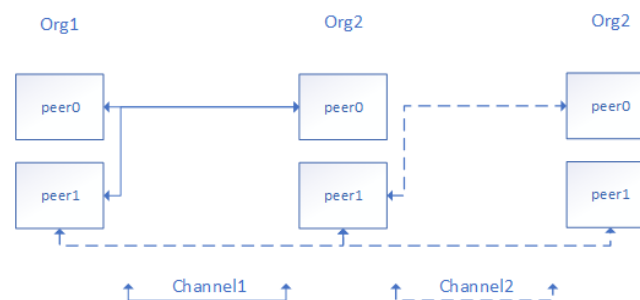


Fig. 3 - Hyperledger fabric channels concept. Three organizations with two channels. Transactions passed to the channel are distributed only over the participants in this channel. Every peer can join one or more channels (Org1.peer1), but they are still isolated from each other.

Node, that maintains the state of the ledger is called "peer". But the peer can handle a special role as endorser. Once the channel is created and the allowed peers are joined, the chaincode should be installed. Chaincode is an application written on Golang or Node.js, which defines the "smart contract".

Chaincode and the data in the channel are available only to the nodes, participating the channel, preserving confidentiality. Generally speaking, the chaincode “decides” if the proposed transaction is valid or no. In a greater detail, it could be very complex program with a lot of business logic inside.

Instantiation of the chaincode is important step afterwards. Instantiation must be completed on every peer, who should be an endorser. During instantiation endorsement policy is set. This policy defines which and how many peers (endorsers) should execute the installed chaincode on the selected channel against the transaction, in order to prepare it for future processing from the ordering service. The endorsement policy could look like:

“(Org1.peer0 OR Org1.peer1) AND (Org2.peer0)” which means the transaction must be endorsed from one of two Org1 peers and especially from Org2.peer0

If the received endorsements satisfy the policy, the client’s node will send the transaction to the ordering service node also known as “orderer”. Orderer “checks” the transaction endorsements again and if they are valid, “burns” the transaction into a block and broadcasts the block to the peers.

Hyperledger fabric provides identity management service that authenticates every network participant. Every step in the process flow is secured and satisfies “non-repudiation” principle.

From the GDPR’s point of view it fits well technically in Accountability and Traceability requirements. It is undeniable who, when and what sent to the channel. It is also clear when the given organization is added in this channel and who grants the permissions to a given entity to do so.

Cybersecurity aspect in GDPR also could get benefits. Exceptionally strong cryptographic nature of the blockchain combined with identity management provided by Hyperledger fabric, makes the data stored in the blockchain resistant from unauthorized modification. In his article focused over blockchain's role in a cybersecurity (Kshetri, N., 2017), Nir Kshetri makes a deeper research about blockchain's role in strengthening cybersecurity and data privacy. He also noticed the blockchain's role in a post-breach resilience plan and implementation.

The technology has also another great benefit - it is distributed. That means, that even a large set of peers to be out of order, if the topology is scaled properly the availability of the service is not affected. When the failed peer goes in active state, it could sync the blockchains from any other peer.

Hyperledger fabric is applicable in the Accuracy also. Hyperledger fabric distributed ledger consist of two components. World state and transaction log. World state keeps the current ledger state, but transaction log keeps all previous transactions which leads to the current world state. Thus, once the transaction is ordered and broadcasted to the peers, all parties included in the channel will see the new data almost immediately.

## **7. Related work**

The possible blockchain usage together with GDPR frameworks isn't isolated research. An elegant solution for "The right to be forgotten" conflict with the blockchain's Immutability, proposed the Chainfrog company in its article (Chainfrog, 2017). They propose several options like: record personal data pseudo-anonymously; encrypt the data on the blockchain; store the data in a referenced encrypted database. But Chainfrog's article raises another concern, about the right of EU persons to contest automated decisions which addresses smart contracts - as programmed logic aka. automated decisions. Another article that analyzes the impact of the GDPR over the blockchain technology is "A guide of blockchain and data protection" (Maxwell and Salmon, 2017). It provides a good overview about hashing technology, variety of blockchain systems, blockchain data protection impact assessments and their impact with data protection principles. In parallel “Gran Thornton” company (Gran Thornton, 2018) also provides solution about data removal, data modification and confidentiality, based on logical "private channels" with encrypted data available only to the participating nodes. Each time when nodes need to update or remove data, the corresponding decryption key of the old data should be removed.

## **8. Conclusion**

The blockchain framework Hyperledger fabric has a lot of advantages, which can be used in conjunction with any software for data processing, even those required for very strict GDPR operations. Hyperledger fabric scalability, modularity, all levels identity management, confidentiality and privacy features build on top of intrinsic blockchain distributed and secure nature, seems to be the right technology candidate here. The benefits from such framework architecture would be:

- It facilitates the fulfillment of contractual obligations of controllers and processors involved in the transmission and processing of personal data;
- It strengthens the credibility of participating organization's confidentiality policies;
- It integrates a level of trust in data exchange interfaces with other organizations;
- Ensures evidence in inspections and investigations;
- Creates opportunities for clear policies and procedures for personal data breaches.

But there is an issue. An issue which confirms the sentence “there is no single development, in either technology or management technique, which by itself promises even one order-of-magnitude improvement within a decade in productivity, in reliability, in simplicity”. (Brooks, F., 1986) The issue with a fundamental blockchain feature: The blockchain is immutable.



It is very difficult to do any modification in a block already added. That could lead to some difficulties from the GDPR point of view. Especially with one right of the data subject - Right to erasure ("Right to be forgotten"). Even if the controller issues a transaction to delete data from the world state component, the data is still in the transaction log. It is still in the blockchain, stored securely in every one peer's storage.

The present article leaves this problem for a future research. The possible solutions should not be searched with blockchain hacks like "editable blockchain" for example. The better approach should be to combine existing technologies patterns with the newly unleashed features of the blockchain.

## Acknowledgements

This research was supported by the Bulgarian FNI fund through the project "Conceptual Modeling and Simulation of Internet of Things Ecosystems (KoMEIN)", contract DN 02/1.

## References

- Brooks, F. P., No Silver Bullet-Essence and Accident in Software Engineering, *Proceedings of the IFIP Tenth World Computing Conference*, (1986).
- Gran Thornton, *GDPR & blockchain - Blockchain solution to General Data Protection Regulation*, Gran Thornton, (2018).
- Hern, A., *Bitcoin mining consumes more electricity a year than Ireland*, *The Guardian*, (2017).
- Kshetri, N., *Blockchain's roles in strengthening cybersecurity and protecting privacy*. Telecommunications policy, (2017).
- Maxwell W., Salmon J., *A guide to blockchain and data protection*, Hogan Lovells, (2017).
- Natarajan H., Krause S., Gradstein H., *Distributed Ledger Technology (DLT) and Blockchain*. <http://documents.worldbank.org/curated/en/177911513714062215/Distributed-Ledger-Technology-DLT-and-blockchain>, (2017).
- Yaga D., Mell P., Roby N., Scarfone K., *Blockchain Technology Overview*. Draft NISTIR 8202, (2018).
- Zheng., Xie S., Dai H., Chen X., Wang H., *An Overview of Blockchain Technology: Architecture, Consensus, and Future Trends*, *2017 IEEE 6th International Congress on Big Data*, (2017).
- Concil of the European Union., *REGULATION (EU) 2016/679 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of on the protection of natural persons with regard to the processing of personal data and on the free movement of such data, and repealing Directive 95/46/EC (General Data Protection Regulation)*, <http://data.consilium.europa.eu/doc/document/ST-5419-2016-INIT/en/pdf>, (2016).
- Chainfrog, *Blockchain and GDPR*, Chainfrog, (2017).
- EU GDPR portal., <https://www.eugdpr.org/>, (2018).
- Forrester., *Predictions 2018 A year of reckoning, Annual edition predictions*, (2017)
- Gartner., *Gartner Says Organizations Are Unprepared for the 2018 European Data Protection Regulation*, *Gartner newsroom*, (2017).
- Hyperledger, *hyperledger-fabric docs Documentation Release master*. (2018).
- Hyperledger fabric, <<https://www.hyperledger.org/projects/fabric>>, (2018).
- ICO., *Guide to the General Data Protection Regulation (GDPR)*, <https://ico.org.uk/for-organisations/guide-to-the-general-data-protection-regulation-gdpr/accountability-and-governance/>, (2018).
- ISO., *Health informatics. ISO/TS 25237:2008*, (2008).

# Algorithms for graph isomorphism. A comparative study

Gheorghica Radu-Iulian<sup>a\*</sup>

<sup>a</sup> Babeş-Bolyai University, Str. Mihail Kogălniceanu, nr. 1, Cluj-Napoca, 400084, Romania

---

## Abstract

Motif graphs are subgraphs that occur multiple times in a network or a variety of networks. The matching of such graphs bears the name “graph isomorphism”. Each subgraph is defined by a set of interactions between nodes and can provide insight about the functionalities of a network that is why, counting them represents a challenge regarding execution times. Given a query graph  $q$  and a data graph  $g$ , we aim to find all occurrences of  $q$  in  $g$ . They have practical implementations in biochemistry, neurobiology and for any problem that can be modeled using graphs. We will describe a comparative study between two existing algorithms, namely VF2 and GADDI, by looking at their pruning techniques and execution times using the Python implementation that I have made in my training stage.

*Keywords:* Graph; motif; isomorphism; network.

---

## 1. Introduction

An induced subgraph (Wikipedia Induced Subgraph) is formed from a subset of the vertices of the graph from which it is extracted that also keeps the edges between them. A network motif is an induced subgraph with the number of occurrences of at least the value of a predetermined threshold. Finding a motif in a network describes a characteristic of said network and such detection is a computationally challenging problem. It has uses (Wikipedia Network Motif) in biochemistry (Figure 1), neurobiology, ecology, genetics, engineering and any domain whose problems can be represented as graphs.

## 2. Literature review. Definitions. Algorithms

There are two types of research directions:

- Subgraph isomorphism: Verifying the existence of a graph in one or more networks and deciding if such a graph is a “motif” according to a minimum number of occurrences (Ullmann (J. R. Ullmann, 1976), VF2 (Cordella et al., 2004), GADDI (Zhang et al., 2009), QuickSI (Shang et al., 2008), SPath (Zhao and Han, 2010), GraphQL (He and Singh, 2008))
- Graph mining: Verifying the existence and counting of frequent subgraphs in one or more networks (gSpan (Yan and Han, 2002)).

Definition (Wikipedia Induced Subgraph): Let  $G = (V, E)$  and  $G' = (V', E')$  be two graphs. Graph  $G'$  is a subgraph of graph  $G$  (written as  $G' \subseteq G$ ) if  $V' \subseteq V$  and  $E' \subseteq E \cap (V' \times V')$ . If  $G' \subseteq G$  and  $G'$  contains all of the edges  $\langle u, v \rangle \in E$  with  $u, v \in V'$ , then  $G'$  is an induced subgraph of  $G$ . We call  $G'$  and  $G$  isomorphic (written as  $G' \leftrightarrow G$ ), if there exists a bijection (one-to-one)  $f: V' \rightarrow V$  with  $\langle u, v \rangle \in E' \Leftrightarrow \langle f(u), f(v) \rangle \in E$  for all  $u, v \in V'$ . The mapping  $f$  is called an isomorphism between  $G$  and  $G'$  (Diestel, 2005).

When  $G'' \subset G$  and there exists an isomorphism between the subgraph  $G''$  and a graph  $G'$ , this mapping represents an appearance of  $G'$  in  $G$ .

The number of appearances of graph  $G'$  in  $G$  is called the frequency  $F_G$  of  $G'$  in  $G$ . A graph is called recurrent (or frequent) in  $G$ , when its frequency  $F_G(G')$  is above a predefined threshold or cut-off value.

Algorithm 1 GenericQueryProc (Jinsoo Lee et al., 2012)

---

\* Corresponding author. Tel.: +40765462837

E-mail address: gheorghica.radu@cs.ubbcluj.ro

Input: query graph  $q$

Input: data graph  $g$

Output: all subgraph isomorphisms of  $q$  in  $g$

```

1:  $M := \emptyset$ ;
2: for each  $u \in V(q)$  do
3:    $C(u) := \text{FilterCandidates}(q, g, u, \dots)$ ;
    $[[ \forall v \in C(u)((v \in V(g)) \wedge (L(u) \subseteq L(v))) ]]$ 
4:   if  $C(u) = \emptyset$  then
5:     return;
6:   end if
7: end for
8: SubgraphSearch( $q, g, M, \dots$ );

Subroutine SubgraphSearch( $q, g, M, \dots$ )
1: if  $|M| = |V(q)|$  then
2:   report  $M$ ;
3: else
4:    $u := \text{NextQueryVertex}(\dots)$ ;
    $[[ u \in V(q) \wedge \forall(u', v) \in M(u' \neq u) ]]$ 
5:    $C_R := \text{RefineCandidates}(M, u, C(u), \dots)$ ;
    $[[ C_R \subseteq C(u) ]]$ 
6:   for each  $v \in C_R$  such that  $v$  is not yet matched do
7:     if IsJoinable( $q, g, M, u, v, \dots$ ) then
8:        $[[ \forall(u', v') \in M((u, u') \in E(q) \Rightarrow$ 
         $(v, v') \in E(g) \wedge L(u, u') = L(v, v')) ]]$ 
9:       UpdateState( $M, u, v, \dots$ );
        $[[ \text{append}(u, v) \text{ to } M ]]$ 
10:      SubgraphSearch( $q, g, M, \dots$ );
11:      RestoreState( $M, u, v, \dots$ );
        $[[ \text{remove}(u, v) \text{ from } M ]]$ 
12:     end if
13:   end for
14: end if

```

For the implementation of the following two algorithms I have used the Python programming language and NetworkX as a means for creating and manipulating undirected graphs. The core of these backtracking algorithms are the pruning techniques, designed for ruling out unnecessary candidates from the data graph.

Refining the candidate set for the query graph means less resources spent on trying to match the query algorithm to one of many data graph induced subgraphs.

Unless the query graph can be fully matched to one of the data graph subgraphs, we cannot consider it an embedding.

This means that at some point in the matching process if a part of the query graph cannot be matched, we already wasted system resources by attempting to find a full embedding, only to discard the already matched query vertices and restart the matching process while risking the same partial matching.

In the Figure 1 there are two examples.

GADDI removes any vertex  $v$  in the candidates set  $C(u)$  if for each query vertex  $u' \in N_k(u)$  there is no data vertex  $v' \in N_k(v)$  satisfying the following conditions:

1)  $L(u') \subseteq L(v')$  - The labels of the selected query graph vertex must be included or equal to the label of the selected candidate vertex from the data graph. For example, in Figure 1(a) we have node  $u_2$  with label "B", which according to the first rule, can be considered for a match with vertices  $v_2, v_5, v_7$  and  $v_8$ , even if for vertices  $v_5$  and  $v_7$  we have composite labels. From the implementation point of view, we must verify if every element of the query vertex label set exists in the set which represents the data vertex label. If true, then we can proceed to apply the second pruning technique.

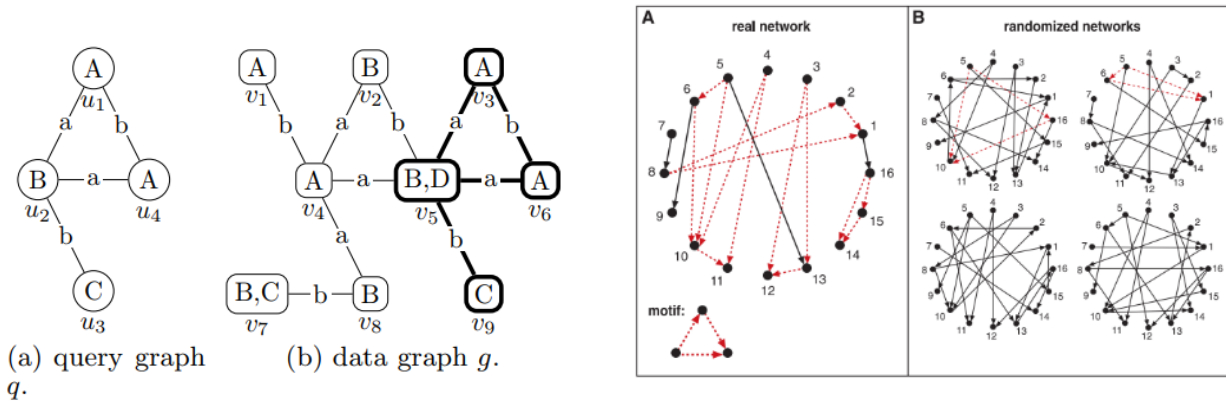


Fig. 1. (a) query graph and a data graph (Jinsoo Lee et al., 2012); (b) motif graph, a real network and randomized networks (Milo et al., 2002)

2) for each  $P_i$  in a given set of substructures,  $\Delta NDS(u', u, P_i) \leq \Delta NDS(v', v, P_i)$  - First, we will see how we obtain the set of substructures. We can do this either by using a frequent subgraph mining tool or a subgraph isomorphism algorithm. The mining tool approach proceeds as follows: according to Jinsoo Lee et al., 2012 and Zhang et al., 2009 the three most frequent substructures are obtained by first randomly choosing 100 edges from the data graph. For each edge, we use its vertices to obtain two neighbourhood graphs of radius  $k$ , with  $k$  being an input parameter for the algorithm. For example, given a vertex, a neighbourhood graph of radius = 1 is formed by including the adjacent vertices of said vertex along with the edges between it and those neighbours and the edges connecting the neighbours.

For radius = 2 I include the neighbours of the previous neighbours and their respective edges and so on. After obtaining two such neighbourhoods we generate a graph by intersecting the sets of edges for them. In our case, even though our dataset graphs are undirected, the order of the vertices in an edge can still affect the outcome of this intersection. Thus, instead of doing an intersection of two edge lists, which in turn are lists of two elements representing vertices, I have used the “has\_edge” method of NetworkX which returns “True” whenever the case, regardless of the order of vertices in the edges.

We store the 100 intersection-graphs in a file under a format that can be interpreted by a frequent subgraph mining tool. For this I have used a command line tool (Betterenvi, 2018) that implements the gSpan algorithm. This tool has another useful feature that makes possible specifying the graph in which each frequent subgraph is found. We will see further on how we apply this.

The manual tool usage is not feasible since due to the randomness of the 100 intersection-graphs, there are very small chances the input files will be the same. So one way I have implemented this is to initialize the console interface of the tool by using specific Python commands and issue the mining initialization automatically. This proved not to be useful, because the Python program would either not wait for the execution of the tool, or I would have to ask for keyboard input which would have been provided in case the tool was finished. It would only have been the initial problem under a different shape. Also, sometimes the tool would raise a memory error and the mining results would be partial.

So, using “pip”, the Python package manager, I have installed the mining tool, imported the package in the project, and called the methods of the tool, avoiding the usage of the console interface altogether. After generating the frequent subgraphs, we read the gSpan output files and generate undirected graph objects using NetworkX. The new graphs do not have the same vertex IDs (not labels; in Figure 1(a), the node with ID =  $u_1$  has the label “A”). This can be considered a bridging between the different IDs of the generated graphs and the ones that will be generated and are necessary in order to have a complete implementation of the  $\Delta NDS()$  method.

Afterwards, I create a matrix having 100 lines, corresponding to the 100 intersection-graphs, and as many columns as the number of frequent subgraphs generated by gSpan.

This is where we need the list of graphs in which each of the frequent subgraphs are found, as previously mentioned. For each frequent subgraph object, we attach its corresponding list as a property using NetworkX.

We need this in order to access the ID of each graph in the list and use it as a column selector. Each element of the matrix will either have its value equal to 1 or 0. This means that in an intersection-graph (a selected line of the matrix) either none of the frequent subgraphs exist, in which case the value on each column would be 0, some or all of them may exist, meaning that the corresponding element or elements in the matrix would be 1.

According to Zhang et al., 2009 I can select frequent subgraphs of either three or four edges, in order to save computation time and not take into account the labels for vertices or edges for the same reason. I have found that we can further optimize this by selecting only the frequent subgraphs with that number of edges that are also found in each of the intersection-graphs. We can easily do this by checking for each “where” list if all of the original 100 graph IDs can be found.

Next, in a unidimensional array with its length equal to the width of the described matrix, we will store in each element the sum of all the elements from each column. We will retrieve the three highest valued elements and then their corresponding frequent subgraphs by using the column coordinate as the graph ID.

These will be the top three most frequent patterns for which we will count the existence in the query graph and the data graph. For the following procedure I have multiple attempts and due to implementation difficulties, I will describe it as a future development plan.

The number of occurrences of each of the three most frequent patterns will be returned by  $\Delta$ NDS (vertex\_1, vertex\_2, Pi) like this: just like before we will need to generate an intersection-graph, but only for the two vertices given, and then using gSpan we will obtain the most frequent subgraphs for it and then count how many times we find the selected most frequent pattern Pi in these subgraphs.

We then return this counter as output data of the method. Since, as mentioned before, gSpan reassigns IDs for vertices as 1, 2, and so on, we only have to check the equality between the IDs of the vertices. I also provide for this method input parameters to specify the radius of the neighbourhood graphs and if the method should search in either the query or the data graph.

Due to the small implementation difficulty described previously, I attempted an alternative approach to generate the three most frequent subgraphs, without using a mining tool (Yanagiba, 2013). Its execution time is larger, but it is easier to understand the process of generating such patterns. Here I used only subgraphs with three edges. First, using NetworkX we generate a complete graph with three edges that will serve as a model for the frequent subgraphs.

By trying combinations of three edges at a time taken from the data graph, we verify which of these edges are connected between each other. For those that are, we store them in a list. I make a copy of the list and for each element in one list, I verify if it is isomorphic with each one from the second. We could optimize this by recording which of the subgraphs in the second list are isomorphic with the selected one from the first list, such that when we reach them in the first list, we could simply skip them. Then, whenever two such subgraphs are isomorphic, we count that as an occurrence and at the end of this procedure we will select the subgraphs with the top three number of occurrences.

Whenever we will call  $\Delta$ NDS (vertex\_1, vertex\_2, Pi), we will do it for each of these three and count their occurrences in the intersection-graph generated for the two input vertices in the same manner as we did before. The two vertices will be selected from the query graph and another two from the data graph and will be executed for all three most frequent subgraphs.

If the counting value of the first is less or equal to the counting value of the second, we proceed to apply the third pruning technique. As a small example, we have the following undirected graph represented as a set of edges: [(0, 1), (1, 2), (2, 3)]. It is isomorphic with [(1, 0), (1, 2), (2, 3)], [(1, 2), (0, 1), (2, 3)] and [(1, 2), (1, 0), (2, 3)]. It is not isomorphic with a graph having four edges, so to do this check we must extract all the subgraphs with three edges from it.

3) the shortest distance between  $u'$  and  $u$  is greater than or equal to the shortest distance between  $v'$  and  $v$ .

We can do this by using NetworkX for returning the shortest path length for each of the two vertices. The vertex  $v'$  belongs to the neighbourhood of radius  $k$  for the vertex  $v$ . We have the same for  $u'$  and  $u$ .

For VF2 there are the following three pruning rules to refine the data vertex candidates:

(1) I remove any candidate vertex of the query vertex such that they are not connected from already matched data vertices. With this, I am sure that no such candidate data vertex has any edge between it and any of the candidates that have been matched with query vertices.

(2) Let  $M_q$  and  $M_g$  be a set of matched query vertices and a set of matched data vertices, respectively. Let  $C_q$  and  $C_g$  be a set of adjacent and not-yet-matched query vertices connected from  $M_q$  and a set of adjacent and not-yet-matched data vertices connected from  $M_g$ , respectively. Let  $\text{adj}(u)$  be a set of adjacent vertices to a vertex  $u$ . Then, prune out any vertex  $v$  in  $C(u)$  such that  $|C_q \cap \text{adj}(u)| > |C_g \cap \text{adj}(v)|$ . For this, we make a list in which we hold the candidate vertices in lexicographic order. We make the first intersection which is  $C_q \cap \text{adj}(u)$ , we do the same for  $C_g \cap \text{adj}(v)$ . The next step is to check if the number of elements in the first set is larger than the ones in the second set. If true, we eliminate  $v$  from a separate list in which we keep the candidates and from which we can safely remove them as necessary.

(3) We also remove any vertex  $v$  in  $C(u)$  such that  $|\text{adj}(u) \setminus C_q \setminus M_q| > |\text{adj}(v) \setminus C_g \setminus M_g|$ . In this case, we make the first subtraction. For every element in  $C_q$ , we remove the ones that have the same ID as any of the neighbours of radius = 1 of  $u$ . We do the same for  $M_q$  and we repeat the whole procedure for the data vertex  $v$ .

### 3. Experimental results

Table 1. Execution times, first match  $M = [{"u1"}]$  for the small dataset,  $M = [{"0"}]$  (test for result accuracy) and  $M = [{"0"}, {"1173"}]$  for the large dataset (Ferro et al.).

Algorithm name	Small dataset[han], $M = [{"u1"}, {"v3"}]$	Large dataset[RI], $M = [{"0"}, {"0"}]$	Large dataset[RI], $M = [{"0"}, {"1173"}]$
VF2	0.0025462 seconds	2.4848946 seconds	7.5494961 seconds
GADDI, radius = 2	94.5596868 seconds	6 to 12 hours	6 to 12 hours

### 3.1 Computer specifications:

- Processor: Intel(R) Core(TM) i7-6700HQ CPU @ 2.60GHz
- RAM: 8.00 GB
- System type: Windows 10, 64-bit
- Disk: Intel SSD 240 GB.
- Python version: Anaconda, Python version 3.6

## 4. Future development

- Prevent the case when sometimes 1 or 2 extra edges would appear in the final result.
- Finish the  $\Delta$ NDS (vertex\_1, vertex\_2, Pi) version in which I use gSpan.

## 5. Conclusions

In this paper I have studied two algorithms for isomorphism finding: GADDI and VF2. For this, I made my own implementation without using the original authors' source code, but only by studying the articles. I described the essential parts of the implementation and made a comparison of the execution times using a small and a large dataset.

## Acknowledgements

This research was supported by Babeş-Bolyai University, Faculty of Mathematics and Computer Science. I would like to thank prof. univ. dr. Pârv Bazil who provided insight and expertise in helping me learn graph theory and how to implement and understand graph isomorphism algorithms.

## References

- Anaconda Cloud. <https://anaconda.org/>
- Betterenvi, *Python implementation of frequent subgraph mining algorithm gSpan*, (2018), <https://github.com/betterenvi/gSpan>
- Cordella, L. P., Foggia, P., Sansone, C., Vento, M. A *(sub)graph isomorphism algorithm for matching large graphs*. IEEE PAMI, 26(10):1367–1372, (2004).
- Diestel R. *Graph Theory (Graduate Texts in Mathematics)*, page 173. New York: Springer-Verlag Heidelberg, (2005).
- Ferro, A., Pulvirenti, A., Alaimo, S., Micale, G., Marceca, G.P., Sciacca, E., Maria, A.D., Sciacca, E., Ferlita, A.L., Martorana, E. University of Catania, Department of Clinical and Molecular Biomedicine (MEDBIO), [https://www.researchgate.net/profile/Alfredo\\_Ferro](https://www.researchgate.net/profile/Alfredo_Ferro), <http://www.dmi.unict.it/~ferro/>
- He, H., Singh, A. K. *Graphs-at-a-time: query language and access methods for graph databases*. SIGMOD, pages 405–418, (2008).
- Lee, J., Han, W.-S., Kasperovics, R., Lee, J.-H. *An In-depth Comparison of Subgraph Isomorphism Algorithms in Graph Databases*. PVLDB, (2012).
- Ullmann, J. R. *An algorithm for subgraph isomorphism*. J.ACM, 23:31–42, January (1976).
- Milo, R., Shen-Orr, S.S., Itzkovitz, S., Kashtan, N., Chklovskii, D., Alon, U. *Network motifs: simple building blocks of complex networks*. Science, 298(5594):824–827, (2002).
- NetworkX. <https://networkx.github.io/>
- Python. <https://www.python.org/>
- Shang, H., Zhang, Y., Lin, X., Yu, J.X. *Taming verification hardness: an efficient algorithm for testing subgraph isomorphism*. PVLDB, 1(1):364–375, (2008).
- Wikipedia Induced Subgraph, [https://en.wikipedia.org/wiki/Induced\\_subgraph](https://en.wikipedia.org/wiki/Induced_subgraph)
- Wikipedia Network Motif, [https://en.wikipedia.org/wiki/Network\\_motif](https://en.wikipedia.org/wiki/Network_motif)
- Yan, X., Han, J. *gSpan: Graph-Based Substructure Pattern Mining*. Proc. 2002 of Int. Conf. on Data Mining (ICDM'02), (2002)

- Yanagiba, *How can I extract all possible induced subgraphs from a given graph with networkx*, <https://stackoverflow.com/questions/22180410/how-can-i-extract-all-possible-induced-subgraphs-from-a-given-graph-with-network>, (2013)
- Zhang, S., Li, S., Yang, J. *GADDI: distance index based subgraph matching in biological networks*. EDBT, pages 192–203, (2009).
- Zhao, P., Han, J. *On graph query optimization in large networks*. PVLDB, 3(1):340–351, (2010).



# Real Time Control Strategy for Improving the Plasma Quality in Nonlinear Reactive Ion Etchers

Roxana-Elena Tudoroiu<sup>a</sup>, Sorin-Mihai Radu<sup>a</sup>, Nicolae Tudoroiu<sup>b,\*</sup>

<sup>a</sup>University of Petrosani, 20 University street, 332006 Petrosani, Romania

<sup>b</sup>John Abbott College, 21275 Lakeshore Road, Sainte-Anne-de-Bellevue, QC, H9X 3L9, Canada

---

## Abstract

The main objective of this paper is to investigate control tracking performance of a digital Proportional Integral Derivative (PID) controller, used as an alternative to a continuous PID controller, in order to prove the effective-ness of this control design approach for improving plasma quality of a Reactive Ion Etching process in semiconductor manufacturing industry. The design methodology presented takes place in an attractive real-time MATLAB SIMULINK environment as one of the most powerful software tools provided on the IT soft-ware market. Reactive Ion Etching process is a critical technology for modern VLSI circuit fabrication used in many stages of the manufacturing process. This research work is motivated by the fact that in most of cases the semiconductor equipment is designed to operate at low efficiency in open-loop. Moreover, the Reactive Ion Etching (RIE) is a highly nonlinear and multivariable process, thus the standard continuous PID controllers are not very robust, requiring frequent parameters tuning to achieve acceptable plasma quality performance for different operating points. All of these investigations lead us to the conclusion that by using a most accurate linear Autoregressive Moving Average (ARMA) model of a fully decoupled open-loop RIE process for closed-loop digital PID control de-sign approach it has the capability for controlling the appropriate key plasma parameters such as the Fluorine concentration ions and their dc energy, and is feasible to improve the plasma etching quality indicators of the reactive ion etchers in terms of their selectivity, uniformity, anisotropy and etch depth.

**Keywords:** Plasma RIE quality etcher; Digital PID control design; ARMA model; PGS.

---

## 1. Introduction

The Reactive Ion Etching (RIE) process in radiofrequency glow discharges is among the most methods used for forming via holes in between metals layers in a multichip modules (MCPs) and for achieving the level details necessary to define small features in films as is mentioned in (May et al.,1991), (Tudoroiu, 2001), (Tudoroiu et al., 2003). It is an increasing demand for using the plasma process, especially in VLSI thin film etching applications. Plasma processing assures a valuable control of the composition and of the profile for these components and processes. Vital requirements such as achieving robustness and high quality of the electrical connections and minimum feature sizes for the Metal Oxide Semiconductor (MOS) devices are obtained by controlling the main etching characteristics of the RIE process, among them can be mentioned the etching rate, anisotropy, selectivity, uniformity and etching layer depth. For an application, the etching rates to obtain a good enough throughput in a single wafer tools while the wafer sizes increase, as well as of the anisotropic profiles, the selectivity over thin gate oxides, uniformity and the directionality of plasma processes are optimized by choosing an appropriate selection of the chemical reactants and of the operating conditions for the RIE process equipment. Better insight view of the etching process is essential in improving the control of the etching characteristics of the RIE process to assure a high quality and the future productivity for at very large-scale integration (VLSI) fabrication processes. The paper is organized as follows: in section 2 a brief overview of the RIE process will be covered. In section 3 we present a standard digital PID control design based on a discrete ARMA PGS plant model approach, as preliminary result from our research in this field obtained in (Tudoroiu, 2001). In section 4 will be presented the main MATLAB simulation results for the proposed approach.

---

\*Corresponding author, Tel: +1 (514) 966-5637\*

E-mail address: [ntudoroiu@gmail.com](mailto:ntudoroiu@gmail.com)

Also, for comparison purpose will be analyzed the quality performance and will be proved its effectiveness such that to be used successful in RIE process control. In section 5 will summarize the main contributions of the research paper and we will address some guidelines for the future work.

## 2. The Reactive Ion Etcher description

In this section a brief description from control perspective of the RIE process, equipment and system architecture is made. The attention is focused only on the overall system behavior rather than on individual physical or chemical processes within the plasma reactor and the wafer. The control design is a very hard task since the RIE process is highly nonlinear and multivariable as is revealed in detail and well documented in (Elta et al., 1993), (May et al., 1991), (Hamby et al., 1995), (Hankinson et al., 1997), (Patterson et al., 1977), (Rashap et al., 1995), (Tudoroiu et al., 2003), (Tudoroiu, 2001), (Vincent et al., 1997). Most of plasma control systems are conceived to control the wafer etcher characteristics with the input variables pressure and Radio Frequency (RF) supplied power, and gas flow rates. Well there is no a particular standard and known procedure to follow for inputs selection to predict the etch performance in different machines or identically, or even in the same machine on two different runs as is shown in (Elta et al., 1993), (Hamby et al., 1995), (Hankinson et al., 1997), (Patterson et al., 1977), (Rashap et al., 1995), (Vincent et al., 1997), explained by the variations in plasma properties, and the presence of the disturbances inside the plasma reactor. Also, there is a significant amount of uncertainty in open-loop control system. This is our motivation to design a robust controller that takes into consideration all these disturbances and uncertainties about the process, as well as the nonlinearity and multivariable nature of the RIE process. The RIE process considered in our case study takes place in a plasma reactor – an Applied Materials 8300 Hexode reactive Ion Etcher used at the Control Laboratory of the Michigan University. It is equipped with a high-tech data acquisition system, actuators and sensors appropriate for real-time open-loop or closed-loop feedback control architectures. This reactor is a parallel plate Plasma Reactor Etching system 1000TP type whose configuration is shown in Fig. 1, as in (Elta et al., 1993), (Tudoroiu et al., 2003), (Tudoroiu, 2001).

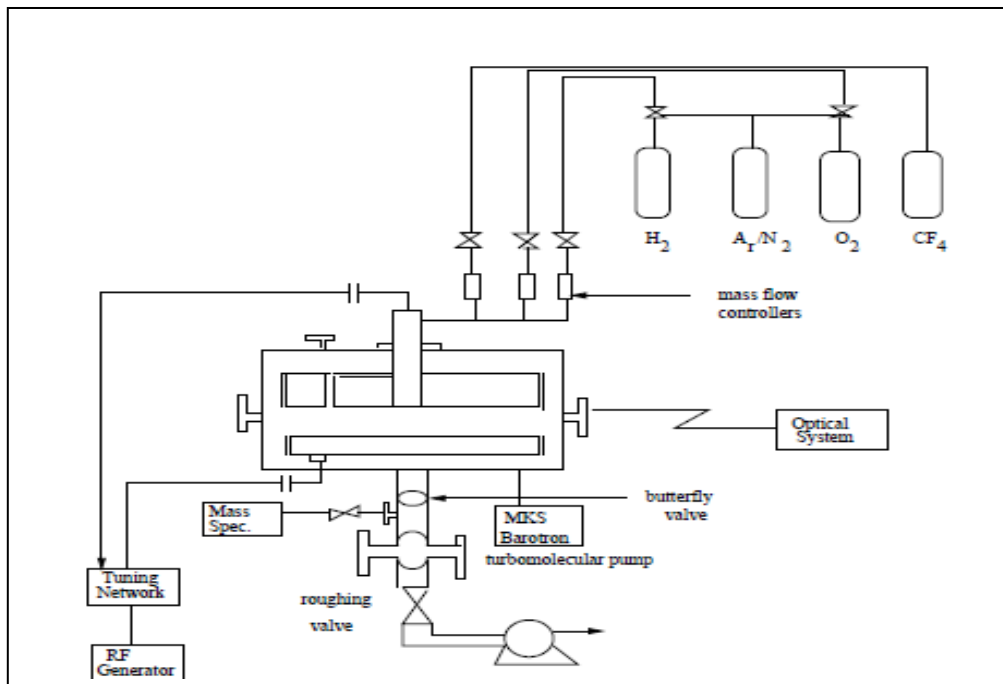


Fig. 1. The layout of the plasma reactor etching system (snapshot view from Tudoroiu, 2001)

More details about this type of plasma reactor can be found in (Elta et al., 1993). Its conceptual decomposition is shown also in figure 2, consisting of two main functional blocks:

- Plasma Generation Subsystem (PGS);
- Wafer Etch Subsystem (WEF).

These sequential subsystems separate the generation of the important chemicals and physical species from the etching action on the surface of the wafer, as is mentioned also in (Tudoroiu et al., 2003), (Tudoroiu, 2001). The two inputs chosen for the PGS are the RF Power and throttle valve position, and as outputs are considered two key plasma parameters fluorine concentration  $[F]$  and dc bias Voltage  $[V_{bias}]$ . Consequently, the PGS subsystem is a Multi-Input Multi-Output (MIMO) control system (*multivariable*) with 2 inputs and 2 outputs, as is shown in Fig.2, (Tudoroiu, 2001).

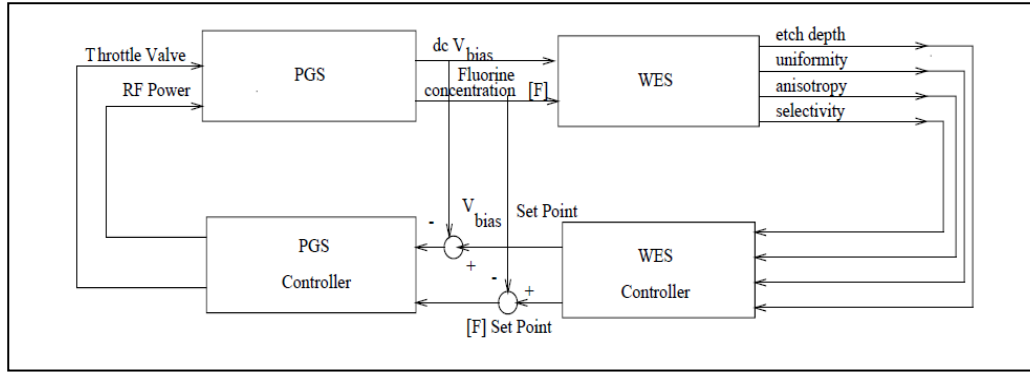


Fig. 2. Schematic diagram of the decomposed structure of the RIE system (snapshot view from Tudoroiu, 2001)

### 3. Digital PID real time controller driving a PGS plant ARMA model design approach

To develop and implement a real-time control strategy in this approach, the PGS is considered as a coupling MIMO control system with two inputs (RF power, and the throttle position of the control valve respectively), and two controlled outputs (dc Bias Voltage and fluorine concentration). The disturbances are the wafer load and the water vapor, considered as deterministic. The fluorine is the dominant etchant species of the chemical reactions that take place in the plasma reactor and the dc Bias Voltage is chosen as measure of the physical energy of the impinging ions. To get a good insight on PGS architecture, its SIMULINK model is shown in Fig.3.

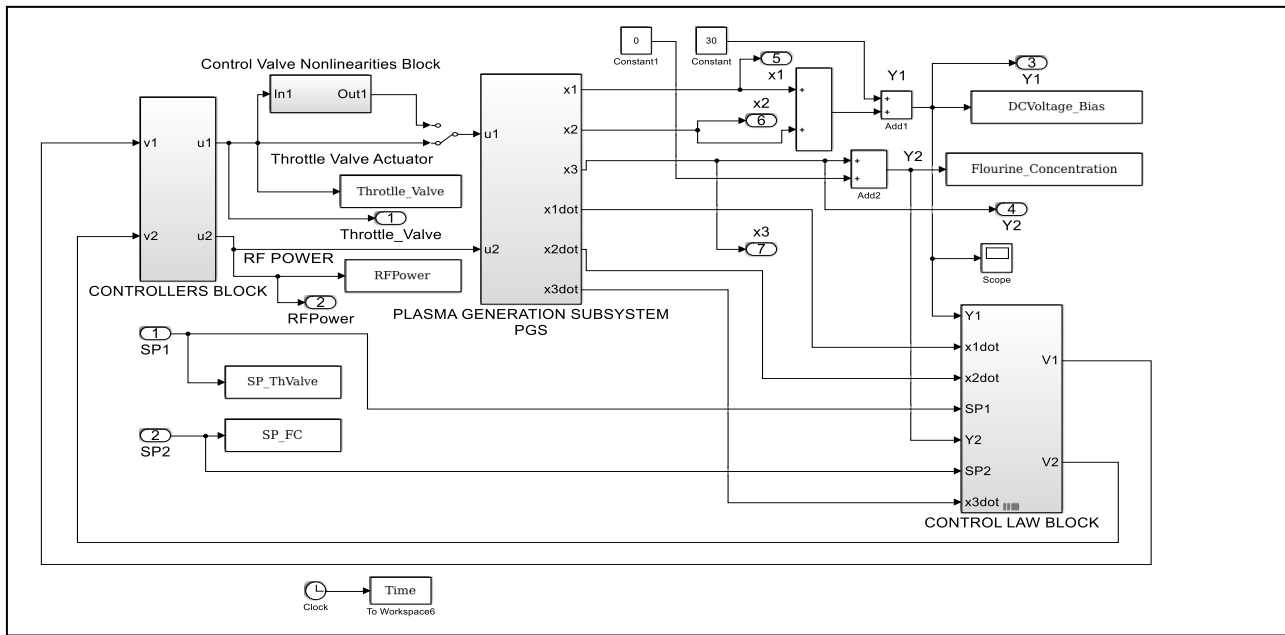


Fig.3. The SIMULINK model of PGS architecture

Technically speaking, the main reason to choose these variables as inputs and outputs of the PGS is firstly to obtain a simple practicable model easy for implementation and a useful support to design different real-time closed-loop control strategies, e.g. a digital PID closed-loop control structure as in our case study. In this approach we consider an Auto Regressive Moving Average (ARMA) PGS model developed in (Tudoroiu, 2001), described by the discrete time decoupled equations:

$$y_1(k+1) = 0.4978y_1(k) + 0.494y_1(k-1) - 2.6879u_1(k) + 2.939u_1(k-1) \quad (1)$$

$$y_2(k+1) = 0.9455y_2(k) + 0.044y_2(k-1) - 0.00001u_2(k) + 0.999923u_2(k-1) \quad (2)$$

Based on the transfer functions in the complex z-domain for each independent channel the design of both PID digital controllers with the SIMULINK blocks is shown in Fig. 4.

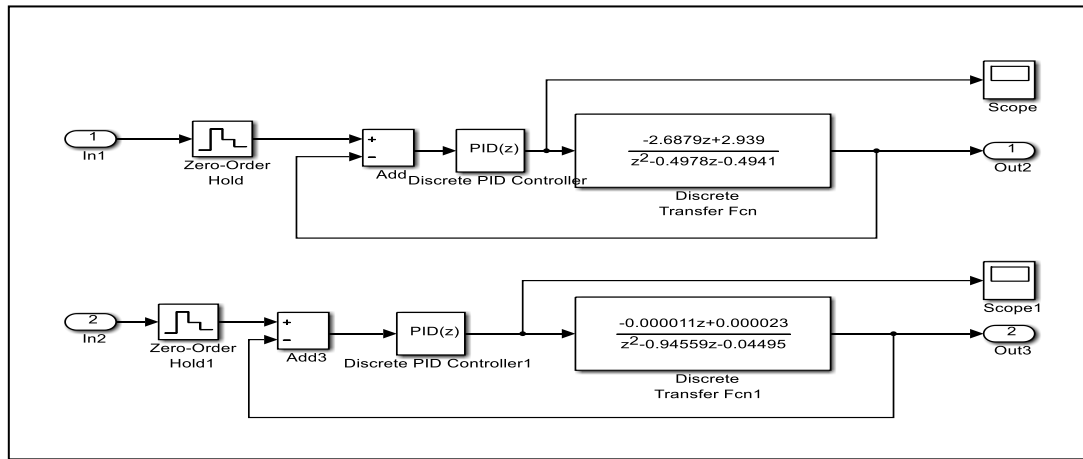


Fig. 4. The SIMULINK model of digital PID PGS ARMA model control approach

#### 4. Simulation results for digital PID ARMA model control design approach

The MATLAB and SIMULINK simulations results for the third control design approach are shown in the Figs. 5 -8.

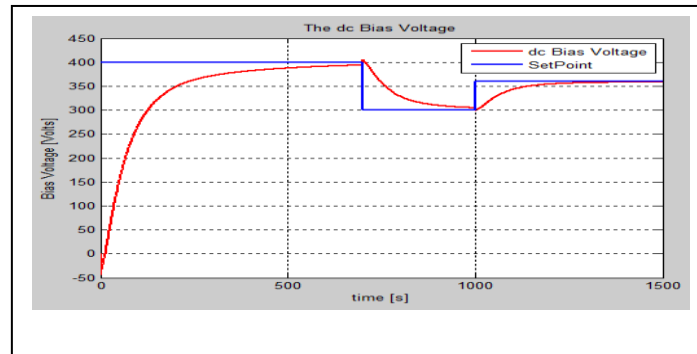


Fig. 5. The MATLAB simulation results for dc Bias Voltage with set point changes

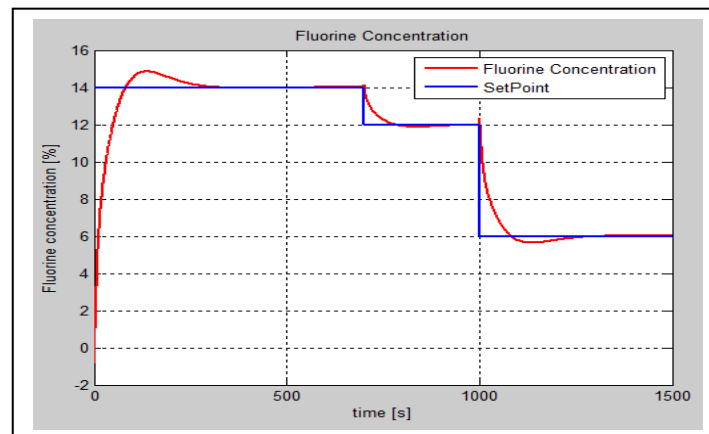


Fig. 6. The MATLAB simulation results for Fluorine concentration with set point changes

In Fig. 5 is shown the evolution of the dc Bias Voltage in this approach with changes in the set point, and similar in Fig. 6 is shown the evolution of Fluorine concentration.

In the both cases we notice a high accuracy of the controllers, but during a long transient, compared to the other control design approaches well developed in [2], for this reason the time scale is changed to  $t \in [0, 1500]$  seconds.

In Fig. 7 is shown the efforts of first controller RF Power control  $u_1$  to track the dc Bias Voltage to the changes in input set point.

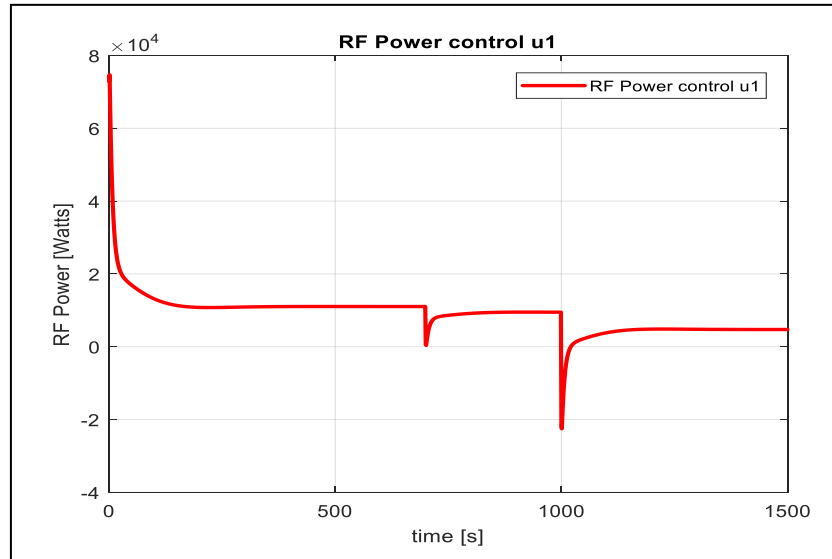


Fig. 7. The RF Power control  $u_1$  efforts to track the dc Bias Voltage

Similar, in Fig.8 is shown the efforts of second controller Throttle valve position control  $u_2$  to track the Fluorine concentration to the changes in input set point.

Also, some robustness tests were made in terms of level noises in the measurement sensors and process, as well as to some deterministic disturbances, and the results were encouraging. Due to space limitations we don't show these additional results. In a future work we will present the results of these robustness tests.

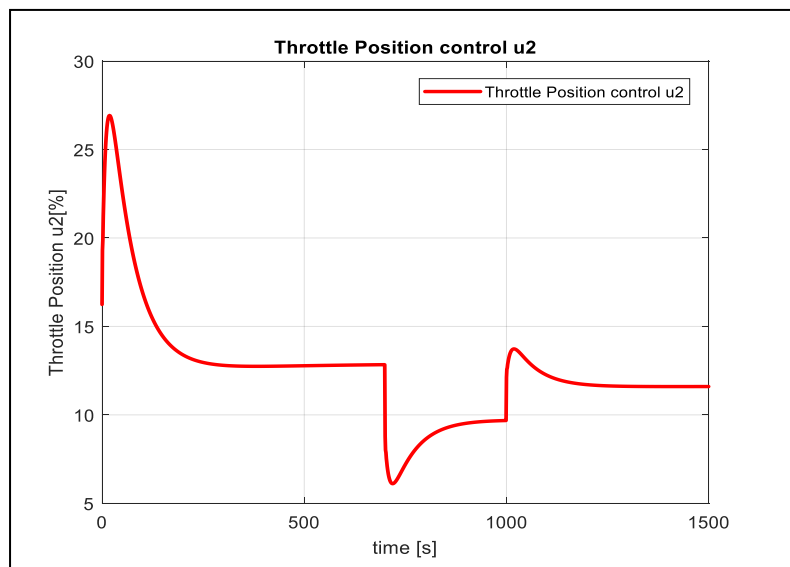


Fig. 8. The Throttle valve position control  $u_2$  efforts to track the Fluorine concentration

## 5. Conclusion

The novelty of this paper is the implementation in real time of a digital PID controller design based on a PGS ARMA discrete model for a highly nonlinear process such as two-scale plasma RIE process, as alternative to an Observer estimator combined with a robust controller as is developed in Tudoroiu et al., 2003. The simulation results are carried out in an attractive real-time MATLAB and SIMULINK simulation environment and reveal the weakness and the strengths of the proposed control design approach to increase the plasma quality performance in RIE etchers. Closing, it is worth to remark that the quality of control design is dependent of nonlinear process characteristics. Consequently, changing the process a new tuning procedure for the parameters values of the process and controllers must be repeated.

## Acknowledgements

For the considerable support and fruitful collaboration in academic scientific research, the correspondent author now has a great opportunity to thank Prof. Dr. Eng. K. K. Khorasani from Concordia University of Montreal, and Prof. Dr. Eng. R.V. Patel from University of Western Ontario, Canada, Prof. Dr. Eng. V. Yurkevich of the State University of Novosibirsk, Russia, and finally the working group of the University of Michigan's Control Laboratory, especially Prof. Dr. Eng. P.P. Khargonekar to provide the necessary experimental data set in research experiments, designing and implementing various control strategies for the RIE process, such as those developed in (Tudoroiu, 2001), (Tudoroiu et al., 2003).

## References

- Elta M. E., Etemad, H., Freudenberg J.S., Giles M.D., Grizzle, J.W., Kabamba P.T, Khargonekar P.P, Lafortune S., Merkov S.M., Moyne J.R., Rashap B.A., Teneketzis D., Terry F. L., Applications of Control to Semiconductor Manufacturing Reactive Ion Etching, *Proceedings of ACC*, San Francisco, California, pp.2990-2995, (1993).
- Hamby E.S., Demos A.T., Kabamba P.T, Khargonekar P.P., A control oriented modeling methodology for plasma enhanced chemical vapor deposition process, *Proceedings of the ACC*, Seattle, pp.220-224, (1995).
- Hankinson M., Vincent T.L., Irani K.B., Khargonekar P.P., Integrated Real-Time and Run-to-Run Control of Etch depth in Reactive Ion Etching, *IEEE Transaction on Semiconductor Manufacturing*, Vol. 10(1), pp.121-130, (1997).
- May G.S., Huang, J., Spanos, C, Statistical experimental design in plasma etch modeling, *IEEE Transaction on Semiconductor Manufacturing*, Vol. 4, pp. 83-98, (1991).
- Patterson O.D., Khargonekar P.P., Reduction of loading effect in reactive Ion Etching using real-Time closed-loop control, *Journal of Electrochemical Society*, Vol. 144(8), pp.2865-2871, (1977).
- Rashap B.A., Elta M. E, Etemad, H., Fournier J.P., Freudenberg J.S., Giles M.D., Grizzle, J.W, Kabamba P.T, Khargonekar P.P, Lafortune S., Moyne J.R., Teneketzis D., Terry F.L., Control of Semiconductor Manufacturing Equipment Real-Time Feedback Control of Reactive Ion Etcher, *IEEE Transaction on Semiconductor Manufacturing*, Vol. 8(3), pp.286- 297, (1995).
- Tudoroiu N, *Application of multivariable and intelligent control strategies for improving plasma characteristics in RIE process*, PhD Thesis, Concordia University from Montreal, Canada, (2001).
- Tudoroiu N., Khorasani, K.K., Yurkevich V., Robust two-time scale control system design for Reactive Etching System, *European Control Conference 2003*, Cambridge, England, September, (2003).
- Vincent T.L., Khargonekar P.P., Terry F.L., End Point and Etch rate Control using Dual-Wavelength Laser reflectometry with a Nonlinear estimator, *Journal of Electrochemical Society*, Vol 144(7), pp.2467-2472, (1997).

## VLC embedded medical system architecture based on medical devices quality requirements

Simona Mirela Rîurean<sup>a\*</sup>, Monica Leba<sup>a</sup>, Andreea Ionică<sup>a</sup>

<sup>a</sup>University of Petrosani, Str.Universitatii, no.20, 332006, Petrosani, Romania

---

### Abstract

Having all over the places wireless data communication has become lately one of the daily habits to all of us. However, as many devices and users hunger for fast wireless Gigabits in the radio frequency (RF) spectrum, the data traffic becomes slower and even jammed. Lately, due to intense research efforts, several possible alternatives to RF data communication has already become mature ready to be launched on the market. One of them is the Visible Light Communication (VLC) technology, not long time ago coined as LiFi. Considering that in many health institutions worldwide using RF for wireless communication is forbidden due to high interferences and therefore potential harmful for patients and damaging effects to medical devices, the VLC data communication emerged as one harmless and suitable alternative. The developed architecture provides communication with/between devices used in the medical environment. This architecture is based on the identification of quality requirements for medical devices according to standards in force.

*Keywords: visible light communication; simulation; ISO 13485; EN 60601; medical healthcare.*

---

### 1. Introduction

Data acquisition and remotely transmission of medical information acquired with the aim of providing expert-based medical care anytime, anywhere to any patient is known as telemedicine. Wireless technologies (Wi-Fi, Bluetooth or ZigBee, WiMAX) for telemedicine have become - for years already - increasingly common both in research studies and daily bases use of medical devices.

VLC, coined in 2011 by Prof Harald Haas - during a TED Conference - as LiFi, has emerged as a new viable alternative solution for wireless data communication, especially for indoor areas where Wi-Fi becomes overcrowded. A special importance for the LiFi is drawn by the medical situations (facilities or medical devices) where RF technologies are limited or even forbidden. LiFi refers to a fully networked, MIMO, full duplex, data wireless communication through light. The VLC prototypes proposed here are intended to be used in a Line of Sight (LOS) scenario for a simplex data wireless communication from one medical device to another in order to allow fast data wireless communication in RF's forbidden areas.

### 2. VLC Versus RF Communication for Telemedicine. Past and Future Challenges

Wireless technologies in telemedicine, support many applications, such as, preserving electronic medical records (EMR), monitoring vital signs, transmitting important information in real time from and to medical staff.

Wireless technologies that are currently being used in medical healthcare facilities and medical devices are most of them based on the Radio Frequency (RF), leading to Wireless Local Area Networks (WLAN), Wireless Personal Area Networks (WPAN), Wireless Body Area Networks (WBAN) built around some wireless standards such as Wi-Fi, Bluetooth, ZigBee or WiMAX (Ng and Chung, 2012). The U.S. Department of Health and Human Services (DHHS), published, in 1977, the first regulation to address the effect of electromagnetic interferences on medical equipment (Gutiérrez et al, 2014).

---

\* Corresponding author. Tel.: +40-744-517-396.  
E-mail address: simonariurean@upet.ro.



Since the use in medical healthcare of RF wireless technologies is dangerous because of the negative effects imposed by the electromagnetic interference (Warnowicz, 1983), (Silberberg, 1993), VLC emerged as a new, and proved to be, harmless wireless communication technology (Shoaib et al, 2016). RF may cause a wide range of medical devices to fail or send error messages and worst, compromise patients' health and safety (Tan et al., 2001), (Huang and Segal, 2012). Boyle, also showed that radiation from RF sources may result in potentially harmful effects towards patients' health (Boyle, 2016).

In contrast to the RF wireless communication that is subject of high interferences with lots of medical devices, VLC, using Light Emitting Diodes (LED) as main actors in the communication system, have been considered as a safe and suitable replacement for RF (Haas, 2017). Due to their advantages (long operational lifetime, energy efficient, high tolerance to humidity, mercury free, compact size and most important, fast switching) LEDs have already successfully replaced, the conventional incandescent, fluorescent and halogen light sources in many illumination networks.

Beside illumination, LEDs are proposed to serve for data wireless communication (Leba et al., 2017), therefore, the VLC technology using white LEDs to transmit data was first demonstrated by 2003 at Nakagawa Laboratory at Keio University in Japan, based on numerical analysis of optical transmission requirements (Tanaka et al, 2003). The most important quality of LEDs - as Solid-State Devices (SSD) is that they ensure communication due to the high frequency response, allowing the light beam to be intensity modulated to carry data piggybacked by illumination (Komine and Nakagawa, 2004).

In their study, Ng and Chung proposed a wireless VLC-based medical healthcare information system as a practical and harmless alternative to RF wireless technology (Ng and Chung, 2012). Several other studies regarding monitoring vital signals based on VLC have been published, an uplink data transmission was proposed and a wavelength division multiplexing (WDM) based bio-medical signal transmission system was introduced in order to increase data transmission rate (Cahyadi, et al. 2015), (Lim et al., 2015), (An and Chung, 2016). An indoor system based on a hybrid Power Line Communication (PLC) with VLC system were proposed for hospital applications (Song et al., 2015), (Ding et al., 2015). A remote health-monitoring system with a highly efficient optical receiver is implemented using VLC as proposed by Al-Qahtani et.al in 2015 (Al-Qahtanie et al, 2015).

An extended study focused on the architectural concepts of the information system for healthcare administrations to deliver personal or public data service using the medical centres illumination network has been proposed by Hong (Hong et al., 2018).

### **3. VLC Based Prototype Development for Medical Use**

#### *3.1. Prototype's Quality Requirements According to ISO 13485 and EN 60601*

The internationally approved standard that draws out all the requirements for a quality management system applied for the medical devices industry is ISO 13485:2016. This standard has been defined in order to be used by specific medical organizations during the life cycle of a medical device, starting with the initial idea to production and post-production, till the final neutralize and disposal. It has been designed to cover aspects like storage guidelines, distribution rules, installation conditions and servicing, as well as the provision of associated services.

The medical device term - according to ISO 13485 - is a product associated with any medical machine, instrument, tool, apparatus, in vitro reagent along with any other similar item intended to be used during the diagnosis process or prevention of illness as well as treatment of disease or any other medical conditions. Today, on the market there are many types of medical devices starting with basic hand tools till sophisticated high-tech machines.

We refer in our paper to the medical resilient devices like:

- wheelchairs (as well as dentist chairs);
- implantable devices like cardiac pacemakers and monitors;
- prosthetic limbs and prosthetic joints;
- life-supporting devices like respirators and lung ventilators;
- sophisticated, software-controlled devices like Computer Tomography (CT) scanners or Magnetic resonance imaging (MRI) machines.

European ISO 13485, as a Quality Management System (QMS) sets the procedures, policies and processes that support an organization in meeting the requirements expected in medical area. It is centered on the Plan-Do-Check-Act cycle, a management method consisting of four steps that are used in business for the control and repeated enhancement of processes and products. In most countries, a QMS is required by regulators in the medical devices industry and qualifies an organization to reliably provide harmless and actual medical devices and achieve specific requirements. Since regulations are quite different from one country to another, ISO 13485 sets general requirements, but requests a medical devices organization to identify those regulatory requirements which are relevant to its individual situation and integrate them into its QMS. Moreover, the standard is compatible with organization's other management systems and allow effectively management of risk, improves processes and efficiency as necessary and gain a competitive advantage.

For the first time, the U.S DHHS received reports (and therefore updated their recommendations) of RF adverse effects on the following electronic medical devices:

- Insulin pumps;
- Electronic devices as cardiac implants (pacemakers and implantable cardioverter defibrillators);
- Neuro-stimulators.

The European standard EN 60601-1:2006 for medical electrical devices suggest general requirements of the many standards for basic safety and critical performance and is widely accepted reference for medical electrical devices and compliance with U.S. IEC60601-1. It has also become a requirement for any electrical medical device launched on the market. This standard defines that all the devices related to vital assistance (critical device) must support a 10 V/m electrical field and that the rest of the devices (non-critical) accept a value of 3 V/m at a frequency from 80 MHz to 2.5 GHz. Furthermore, the standard rules that the medical device must support a magnetic field of 37.8 mG at the industrial frequency (60 Hz). The lowest value set by the standard at high frequencies, is considered 3 V/m, equivalent to 129.5 dB $\mu$ V/m due to the simultaneous presence of critical and non-critical devices (Gutiérrez et al., 2014).

### 3.2. VLC System Embedded in a Medical Device

VLC uses LEDs with white light in the visible spectrum that is not harmful for human eyes and do not affect human's health at all. According to EN 62471:2008 standard for photobiological safety regulation of lamps and lamp systems, incoherent diffuse continuous-wave-modulated LEDs carry no photobiological hazard for the human eye when the irradiance does not exceed 100 W/m<sup>2</sup> at a distance of 0.2 m from the optical source in the direction of maximal directivity within 1000 s (Dimitrov and Haas, 2015). On the other hand, optical wireless communication based on infrared IrDA sources is subject of strict regulations (European Directive 2002/95/EC) regarding the long exposure at high heat loads that can interfere with the temperature balance of the body and can cause tissue damage or accelerate skin aging. Chronic exposure to heat can lead to eye disease (e.g. cataract).

The VLC system proposed is according to the general diagram shown in figure 1. LED allows to be modulated at a high frequency to send binary data (0 and 1). Therefore, for an efficient VLC system, the choice of LED type is important. There are two types of LEDs: white LEDs and a single-colour LEDs (e.g., red, green or blue). White light visible by human eye is generated using one of the two techniques:

- the first technique uses a blue LED coated with a phosphor layer that emits yellow light. An amount of a short wavelength light emitted by the blue LED is absorbed by the phosphor layer, so the emitted light from the absorber results in wavelength shift to a longer wavelength of yellow light. This is the best choice due to the lower complexity and cost. However, the slow response of phosphor limits the modulation bandwidth of the phosphorescent white LEDs to a few MHz (Gfeller et al., 1979).
- combining red ( $\lambda \sim 625$  nm), green ( $\lambda = 525$  nm) and blue ( $\lambda = 470$  nm) (RGB) in a correct proportion (like in a colour television), the white light (or any other colour) can be generated. These triplet devices consist of a single package with three emitters and combining optics, and they are often used in applications where variable color emission is required. These devices are suitable for VLC as they offer the possibility of Wavelength Division Multiplexing (WDM).

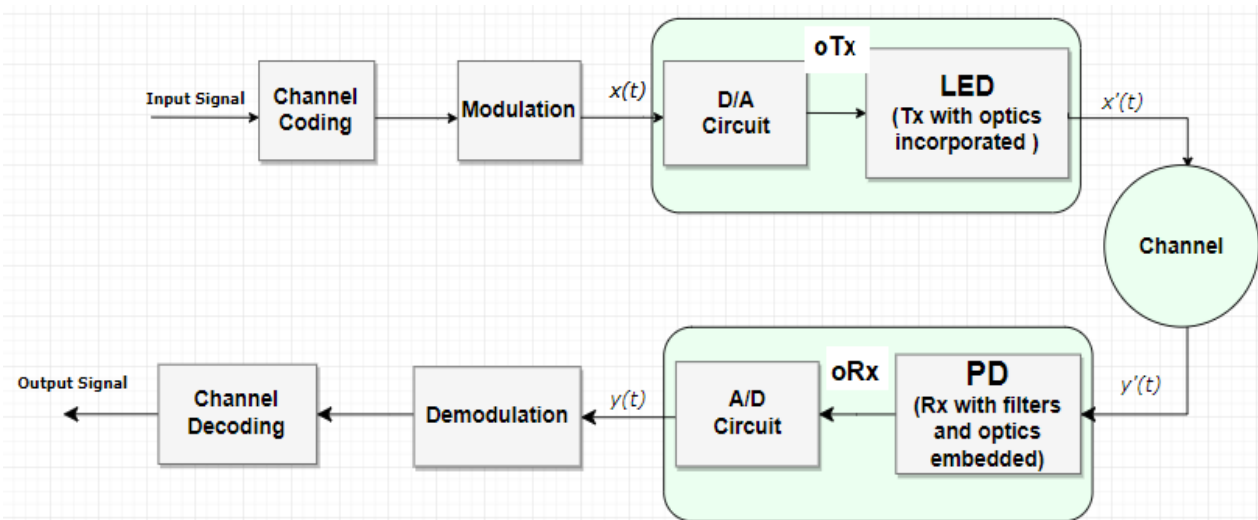


Fig. 1. General Diagram of the VLC system

There are two types of photodiodes (PD) used for VLC: Positive Intrinsic Negative (PIN) and Avalanche Photodiode (APD). APD has higher optical sensitivity (usually 10 dB) than PIN but is also very sensitive to temperature fluctuation. The choice of a detector is made considering its spectral response, area, capacitance and transit-time limited bandwidth effects. The most of the significant signal is carried in the blue range emission, therefore a filter is recommended to be used with the PD. When used with blue filtering, the transmission rate can reach hundreds of Mbps. As shown in figure 1, D/A stands for converting digital signals to analogic, and A/D converts analogic signals into digital signals.

### 3.3. Optical Channel Gain Simulation Conducted Indoor

The indoor position of the optical transmitter (oTx) and optical receiver (oRx) are important, their radiation/detection characteristics as well as the reflection properties of the objects in the environment, therefore we consider a Line of Sight (LoS) scenario as shown in figure 2. As practical experiments showed, in nature, most reflections are diffuse, therefore we can appropriately use the Lambertian model (Gfeller and Bapst, 1979). In order to obtain the Channel Impulse Response (CIR), we took into consideration in the square room of 3x3x2 m (L x l x h) multiple surfaces as different modules of a system with all having the same reflecting elements (plaster walls with 0.8 reflectivity index) and sum the reflected light at the receiver.

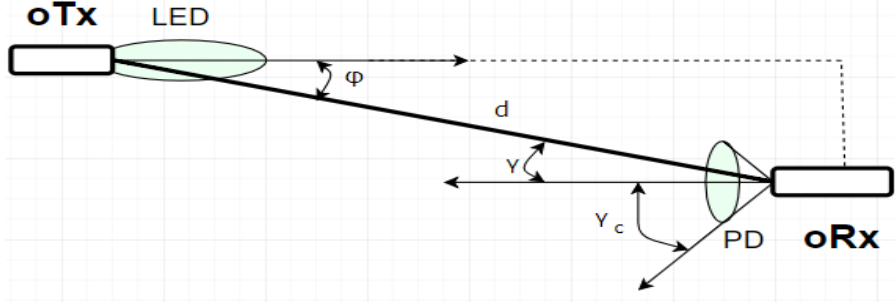


Fig. 2. Geometrical model of the direct NLoS light propagation scenario

The most important characteristics of a LED and a PD as parts of a VLC system are radiation pattern, optical spectral response, electrical modulation bandwidth and the electrical to optical (E/O) conversion. The receiving PD must have a fast response speed in order to properly interpret the transmitted optical signal. We used in our system the two types of LED shown in figure 3.a and PDs shown in 3. b.

We used for our first prototype a 1-Watt cold white LED with (3 chips) from TDS as oTx and 3 Vishay silicon PIN photodiode (fig 3.b left) as oRx. The second prototype has a 1-Watt cold white LED SG-1W as oTx and a BPW PD (fig 3.b right) as oRx.



Fig. 3. LEDs (3.a.) and PDs (3.b.) used in our prototypes

The first prototype consists of a P001L4Z11 LED made of InGaN/Sapphire, with power dissipation 1365 mW, DC forward current 350 mA, pulsed forward current ( $t_p \leq 100\mu s$ , Duty Cycle = 0.005) 700 mA, luminous flux 120 lm, forward voltage 3.3V, view angle ( $\phi$ )  $130^\circ$ . Considering spectral sensitivity and response, BPV10 PIN photodiode is our first choice for oRx. This PD (fig 2 b. left) has a radiant sensitive area of  $0.78\text{mm}^2$ , angle of sensitivity  $\gamma = \pm 40^\circ$ , range of spectral bandwidth  $\lambda_{0.1}$  from 380 to 1100 nm and absolute spectral sensitivity  $s(\lambda)$  0.55 A/W at VR = 5 V,  $\lambda = 950$  nm. The PD's spectral response is important to coincide with the visible light range of the LED transmitted signal.

The second prototype uses a 1 Watt cold white LED 1WCW3K1A1 with a forward current of 350 mA, power dissipation 1.15 W, forward voltage between 3 and 3.8 V, wavelength  $\lambda_c$  (nm) (K) between 8000 and 30000, luminous flux (LM) between 80 and 130, view angle ( $\phi$ )  $120^\circ \pm 5^\circ$ , peak pulsed forward current 800 (mA) 1/10s and a planar Silicon PIN photodiode BPW20R in a (hermetically sealed) short TO-5 case, designed especially for high precision linear applications. The short circuit photocurrent is linear over seven decades of illumination level, due to its extremely high dark resistance. Then again, there is a strictly logarithmic correlation between illumination and open circuit voltage over the same range. Equipped with a clear, flat glass window, the spectral responsivity reaches from blue to near infrared. It has radiant sensitive area  $A = 7.5\text{mm}^2$ , the viewing angle of sensitivity  $\gamma = \pm 50^\circ$ , range of spectral bandwidth  $\lambda_{0.5}$  from 550...1040 nm, relative spectral sensitivity  $s(\lambda)_{\text{rel}}$  0.22 A/W at VR = 5 V,  $\lambda = 410$  nm and  $s(\lambda)$  0.5 A/W at VR = 5 V,  $\lambda = 550$  nm.

The optical LoS link (see figure 2) considered is non-frequency selective with the length relatively short, therefore both attenuation due to the absorption and scattering are very low and we did not consider in this simulation.

The angular distribution of the radiation intensity pattern is modelled using a generalized Lambertian radiant intensity (Carruthers and Kannan, 2002) with the following distribution:

$$R_0(\varphi) = \begin{cases} \frac{(m_1 + 1)}{2\pi} \cos^{m_1}(\varphi), & \varphi \in [-\frac{\pi}{2}, \frac{\pi}{2}] \\ 0, & \varphi \geq \pi/2 \end{cases} \quad (1)$$

where  $m_1$  is the Lambert's mode number expressing directivity of the source beam,  $\varphi = 0$  is the angle of maximum radiated power.

The order of Lambertian emission  $m_1$  is related to the LED semi-angle at half-power  $\varphi_{1/2}$  by:

$$m_1 = \frac{-\ln 2}{\ln(\cos \varphi_{1/2})} \quad (2)$$

The oRx (with the PD area  $A_{PD}$ ) has an optical band-pass filter of transmission  $T_s(\gamma)$  (considered here 1) and a non-imaging concentrator of gain  $g(\gamma)$ , the DC gain for the Rx located at a distance of  $d$  and angle  $\varphi$  with respect to oTx (see figure 2) can be approximated as:

$$H_{LoS} = \begin{cases} \frac{A_{PD}(m_1 + 1)}{2\pi d^2} \cos^m(\varphi) T_s(\gamma) g(\gamma) \cos \gamma, & 0 \leq \gamma \leq \gamma_c \\ 0, & \text{elsewhere} \end{cases} \quad (3)$$

The Lambertian order  $m$  is 1 and the optical gain  $g(\gamma)$  of an ideal non-imaging concentrator having internal refractive

$$h_{LoS} = \frac{A_{PD}(m_1 + 1)}{2\pi d^2} \cos(\varphi) T_s(\gamma) g(\gamma) \cos(\gamma) \delta(t - \frac{d}{c}) \quad (4)$$

$$g(\gamma) = \begin{cases} \frac{n^2}{\sin^2 \gamma_c}, & 0 \leq \gamma \leq \gamma_c \\ 0, & \gamma > \gamma_c \end{cases} \quad (5)$$

index  $n$  (considered here 1.5) is (Tanaka, 2003), where  $\gamma_c \leq \pi/2$  is the Field of View (FoV).

When  $\varphi < 90^\circ$  and  $\gamma < \text{FoV}$  and  $d > (A_{PD})^{1/2}$  the path loss depends on the square of distance between the oTx and oRx, and CIR is expressed as:

where  $c$  is the speed of the light in free space ( $3 \times 10^8 \text{ m/s}$ ),  $\delta(\cdot)$  is the Dirac function and  $\delta(t - d/c)$  represents the signal propagation delay.

Using the above-mentioned equation for our first prototype with the distance of 1 meter between oTx and oRx, the channel gain is shown in figure 4.a and for the second prototype channel gain is shown in figure 4.b.

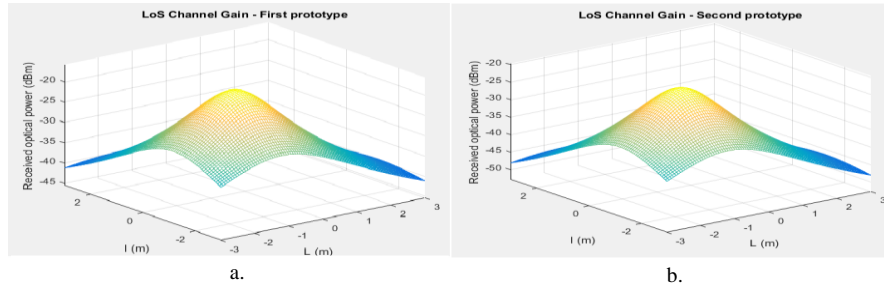


Fig. 4. LoS Channel Gain for the first and second prototype considered

Simulation completed in MatLab (Ghassemlooy et al., 2013) for both prototypes has been done taking into account conditions of the same room (plaster walls with 0.8 reflectivity index, dimensions  $l \times L \times h = 3 \times 3 \times 2$  meters), with the same distance between oTx and oRx (1 m), in the same position with the same non-imaging concentrator and the same optical band-pass filter.

As it can be seen from the simulation above (figures 4 a. and 4 b.) the first prototype (figure 4. a) has a better channel gain - between 41 and 30 dBm than the second one (figure 4. b) with a channel gain between 48 and 36 dBm, due to the technical characteristics of LED and PD used. On the other hand, the second prototype is smaller, cheaper and achieves a better channel gain when the distance between oTx and oRx is shorter (0.5 m for example), so it can be used for simplex, fast data communication between small medical devices placed closed to each other.

#### 4. Conclusions

The VLC prototypes we propose in this paper are intended to be used in a LOS scenario for a simplex data wireless communication between two medical device situated in a medical facility at a distance of 1 meter to each other, fast data wireless communication, in order to avoid any interferences occurring from using multiple devices based on RF communication.

Results show that a LoS visible light simplex data communication between two medical equipment is achievable with low cost on-the-shelf optical devices, thus a very convenient replacement for data communication based on RF which is limited or forbidden in many areas of medical facilities. Both prototypes satisfy the quality requirements of ISO 13485 and EN 60601. The first and most important quality of our prototypes stands in their ubiquitous availability in medical RF forbidden environments (both facilities and medical devices) and indoor fast data communication.

## References

- Al-Qahtani A., Al-Hajri H, Al-Kuwari S., et al., A non-invasive remote health monitoring system using visible light communication, *Proceedings of 2<sup>nd</sup> Int. Symp. on Future Information and Communication Technologies for Ubiquitous Health Care*, Ubi-HealthTech, pp.1–3, (2015).
- An J.Y., Chung W.Y., *Bio-medical data transmission system using multi-level visible light based on resistor ladder circuit*, JSST25 131–137, (2016).
- Boyle J, *Wireless technologies and patient safety in hospitals*, Telemedicine and e-Health 12:373, 10.1089/tmj.2006.12.373, (2006).
- Cahyadi W.A., Jeong T.I, Kim Y.H., Chung Y.H., Adiono T., Patient monitoring using visible light uplink data transmission, *Proceedings of International Symposium on Intelligent Signal Processing and Communication Systems*, ISPACS, pp. 431–434, (2015).
- Carruthers J. B. and Kannan, P. *Iterative site-based modelling for wireless infrared channels* IEEE Transactions on Antennas and Propagation, vol. 50, no. 5, pp. 759–765, May, (2002).
- Dimitrov S., Haas H., *Principles of LED Light Communications: towards Networked Li-Fi*, Cambridge University Press, (2015).
- Ding W., Yang F., Yang H., Wang J., Wang X, et al. *A hybrid power line and visible light communication system for indoor hospital applications*. Coput. Ind. 68 170-178, (2015).
- Ghassemlooy, Z. Popoola, W. Rajbhandari, S., *Optical Wireless Communications. System and Channel Modelling with MATLAB*, CRC Press Taylor & Francis Group, (2013).
- Gfeller F. R., Bapst U., *Wireless in-house data communication via diffuse infrared radiation*, *Proceedings of the IEEE*, 67, 1474–1486, (1979).
- Gutiérrez O, Navarro M.A., Saez de Adana F., Escobar A, Moncada M.E, Muñoz C. M. *Study of Electromagnetic Compatibility in Hospital Environments*, Journal of Electromagnetic Analysis and Applications, 6, 141-155 Published Online June 2014 in SciRes. <http://www.scirp.org/journal/jemaa>, DOI: 10.4236/jemaa.2014.67014, (2014).
- Haas H. *Progress in LED technology removes barriers for LiFi communication*, Optoelectronics & Communications, An interview from SPIE Photonics West, 26 May 2017, SPIE Newsroom. DOI: 10.1117/2.3201705.03, (2017).
- Hong H, Ren Y, Wang CX, *Information illuminating system for healthcare institution*, *International Conference on Bioinformatics Biomedical Engineering*, pp. 801-804, (2008).
- Huang R A, Segal B, *A literature review of the safety of medical body area network devices in magnetic resonance imaging*, *International Symposium of Medical Information Commun. Tech.*, pp. 127-129, (2011).
- Komine T., Nakagawa M., *Fundamental analysis for visible-light communication system using led lights*, IEEE Trans. Consumer Electron. 50 (1) 100–107, <http://dx.doi.org/10.1109/TCE.2004.1277847>, (2004).
- Leba M., Riurean S., Ionica A. *LiFi – the Path to a New Way of Communication*, CISTI'2017 - 12<sup>a</sup> Conferência Ibérica de Sistemas e Tecnologias de Informação, Lisbon, Portugal 21-24 June 2017 IEEE Xplore (2017).
- Lim K.H., Lee H.S., Chung W.Y., *Multichannel visible light communication with wavelength division for medical data transmission*, J. Med. Imaging Health Inf. 5 1947–1951, (2015).
- Ng Xiao-Wei, Chung Wan-Young, *VLC-based medical healthcare information system*, Biomedical Engineering: Applications, Basis and Communications, Vol. 24, No. 2, 155-163 DOI: 10.1142/S1016237212500123, (2012).
- Song J., Ding W., Yang F., Yang H., Yu B., Zhang H., *An indoor broadband broadcasting system based on PLC and VLC*, IEEE Trans. Broadcast. 61, 299– 308, (2015).
- Shoaib M., Syed H. Qasidb A., Rehman S. and Aitzaz Bin Sulttan Ra *Visible light communication applications in healthcare*, Technology and Health Care 24 135–138 DOI 10.3233/THC-151098 IOS Press Short Communication, (2016).
- Silberberg, J. *Performance Degradation of Electronic Medical Devices Due to Electromagnetic Interference*. Compliance Engineering, 5, (1993).
- Tan KS, Hinberg I, Wadhwani J, *Electromagnetic interference in medical devices: Health Canada's past and current perspectives and activities*, *IEEE International Symposium of Electromagnetic Compatibility* 2:1283, (2001).
- Tanaka Y., Komine T., Haruyama S., and Nakagawa M. *Indoor Visible Light Data Transmission System Utilizing White LED Lights*, 8, Aug 2003, IEICE Transactions on Communications, Vols. E86-B, pp. 2440-2454, (2003).
- Warnowicz, A. *The Pacemaker Patient and the Electromagnetic Environment*. *Clinical Progress in Pacing and Electrophysiology*, 1, 166-176. <http://dx.doi.org/10.1111/j.1540-8167.1983.tb01606.x>, (1983).

# Machine learning application detecting potent illicit central nervous system stimulants

Mirela Praisler<sup>a\*</sup>, Stefanut Ciochina<sup>a</sup>, Marian Coman<sup>a</sup>

<sup>a</sup>“Dunarea de Jos” University of Galati, 47 Domneasca Str., Galati 800008, Romania

---

## Abstract

We are presenting a machine learning application built for the automatic recognition of the class membership of the main types of illicit synthetic drugs that are abused for their stimulant and / or hallucinogenic biological activity, as well of their main precursors. The detection is based on spectra recorded between 1550 and 1330 cm<sup>-1</sup> with a portable laser infrared spectrometer. A *wTE* feature weight was determined in order to identify and enhance the most discriminant absorptions. The effect of spectra preprocessing is presented in detail for all the modeled classes of compounds. Principal Component Analysis (PCA) was then performed in order to evaluate the obtained clusters. The discrimination power of each of the main principal components and the potential overlap of the clusters was assessed by using statistical box plots. The bidimensional score plot obtained for the main principal components have been analyzed in conjunction with the corresponding loading plot in order to identify the absorption bands that are contributing to the formation of each cluster. The results recommend the application as an efficient forensic tool.

**Keywords:** drugs of abuse; precursors; machine learning.

---

## 1. Introduction

We are presenting a machine learning application designed to operate a portable laser infrared spectrometer screening for illicit synthetic drugs that are abused for their stimulant and / or hallucinogenic pharmacological activity, as well as their main precursors (Mengali et al., 2013), (Herbst et al., 2012). More specifically, the system is designed to perform the automatic recognition of the class membership of the following class of designer drugs: amphetamine ( $\alpha$ -methylphenethylamine, AMP) and its analogues, tenamphetamine (3,4-methylenedioxyamphetamine, MDA) and its analogues, and ephedrine (*rel*-(*R,S*)-2-(methylamino)-1-phenylpropan-1-ol, EPH) isomers and analogues.

AMP and most of its analogues are stimulants of the central nervous system (CNS). These drugs, especially methamphetamine (MAMP), are often abused for recreational purposes (Karch, 2007). Besides their (moderate) psychological dependence liability and addiction liability, these stimulants may have very severe side effects. Hence, they are controlled in most of the countries (UNODC, 2017).

MDA and its analogues are even more dangerous. Besides their CNS stimulant effect, they also have an important hallucinogenic and euphoriant effect (Laing, 2003). For example, the most frequently abused analogue, midomamphetamine (3,4-methylenedioxymethamphetamine, MDMA), sold on the black market under the name of *Ecstasy*, often leads to paranoia, insomnia and rapid heartbeat. This class of substituted amphetamines may lead to death due to increased body temperature and dehydration. Hence, they have no approved medical uses.

EPH and many of its analogues and isomers (e.g. pseudoephedrine, norephedrine) are often abused by athletes and participants to rave parties (Momaya et al., 2015). They are abused as performance enhancers, as they seem to delay significantly the sensation of fatigue. Although these compounds have a milder CNS stimulant activity and do have some medical uses, they are controlled substances and as closely monitored worldwide as the other two classes of amphetamines mentioned above, because they are the main precursors of stimulant amphetamines (UNODC, 2017).

---

\* Corresponding author. Tel.: +4-072-299-5869 ; fax: +4-023-631-9329.  
E-mail address: Mirela.Praisler@ugal.ro.

During the last decade, a true proliferation of clandestine laboratories has been noticed worldwide. This trend has prompted governments to fund the development of new portable instruments, designed to assist the law enforcement officers during field operations, as well as for border protection (EMCDDA, 2017). Such a prototype has been developed within the DIRAC project, funded by the European Union. This instrument is a portable infrared laser spectrometer designed to perform a fast *in situ* analysis of amphetamines and of their main precursors.

The artificial intelligence application presented in this paper is designed to automatically process the vibrational spectra of the samples and to detect reliably any compound having a molecular structure similar to the targeted parent compounds (AMP, MDA and EPH). The challenge is related to the fact that the class identity assignment is based only on the absorptions recorded in the limited infrared domain (1550 and 1330  $\text{cm}^{-1}$ ) specific to the laser source of radiation of the spectrometer, i.e. the UT7 quantum cascade laser (QCL). This paper describes the computational architecture of the application and the studies performed in order to assess to what extent the system reaches the detection accuracy obtained when the full infrared spectra are available for analysis.

## 2. Experimental part

A spectral database was formed by including the spectra of AMP and six of its analogues (MAMP, EAMP, PAMP, APEA, MAPEA and BPEA), MDA and five of its analogues (MDMA, MDEA, N-OH-MDEA, BDB and MBDB), EPH and five of its isomers and analogues (pseudoephedrine, norephedrine, norpseudoephedrine, N-methylephedrine and benzyephedrine), as well as seventeen negatives, i.e. randomly selected compounds of forensic interest (Praisler et al., 2017). We will further refer to these four classes of compounds as M, T, E and N respectively. The absorptions have been recorded, with a 5  $\text{cm}^{-1}$  resolution, between 1550 and 1330  $\text{cm}^{-1}$ . Hence, the database represents a matrix with 36 x 45 entries.

This database has been used in order to determine a  $w_{TE}$  feature weight (Praisler et al., 2017), based on the Fisher function (see Fig.1). For this purpose, the spectra of T and E compounds have been included in class I, and those of the M and N substances in class II. In order to enhance the cohesion of the clusters, a new database has been obtained by processing the 36 spectra with the  $w_{TE}$  feature weight (Ciochina et al., 2017).

The latter database has been subjected to Principal Component Analysis (PCA) (Jolliffe, 2002). The score plots have been used to assess to what extent the modeled classes of drugs of abuse are clustering and how well-defined (distinguishable one from another) these clusters are. The potential cluster overlap was estimated based on statistical box plots. The score plots, corroborated with the corresponding loading plots, have also indicated the absorption bands (and associated chemical groups) that are contributing to the formation of each cluster. The clustering quality has been compared with that obtained with the full infrared spectra (Praisler and Ciochina, 2014).

## 3. Results and discussion

The  $w_{TE}$  feature weight enhances the absorptions ( $w_{TE} \geq 1$ ) according to their modeling and discrimination power. The intensity of the bands found to be irrelevant for distinguishing between the targeted classes of compounds is left unchanged ( $w_{TE} = 1$ ). Fig. 1 indicates that the most important absorptions are those around 1480, 1445 and 1430  $\text{cm}^{-1}$ .

The effect of spectra processing on the mean spectra of the targeted classes of compounds is illustrated in Fig. 2. The latter indicates that the 1480  $\text{cm}^{-1}$  corresponds to the absorptions specific to the stimulant phenethylamines (M and E) and the absorptions found between 1445 and 1430  $\text{cm}^{-1}$  distinguishes the positives (M, T, E) from the negatives (N).

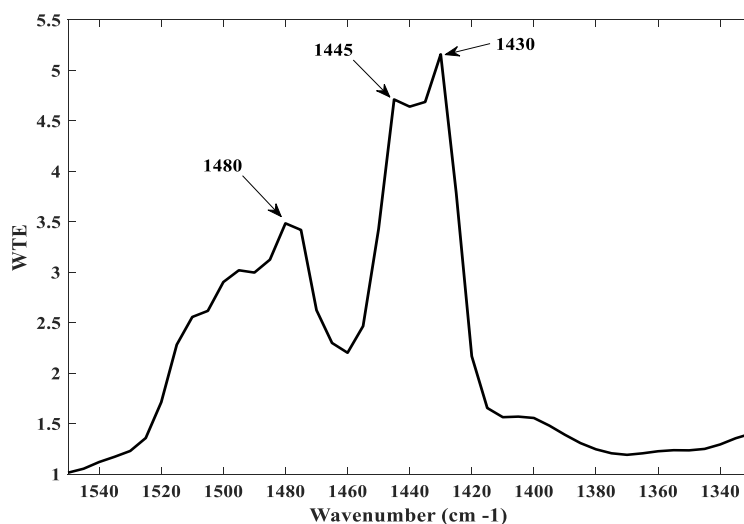


Fig. 1.  $w_{TE}$  feature weight used to process the original spectra in order to obtain the final database



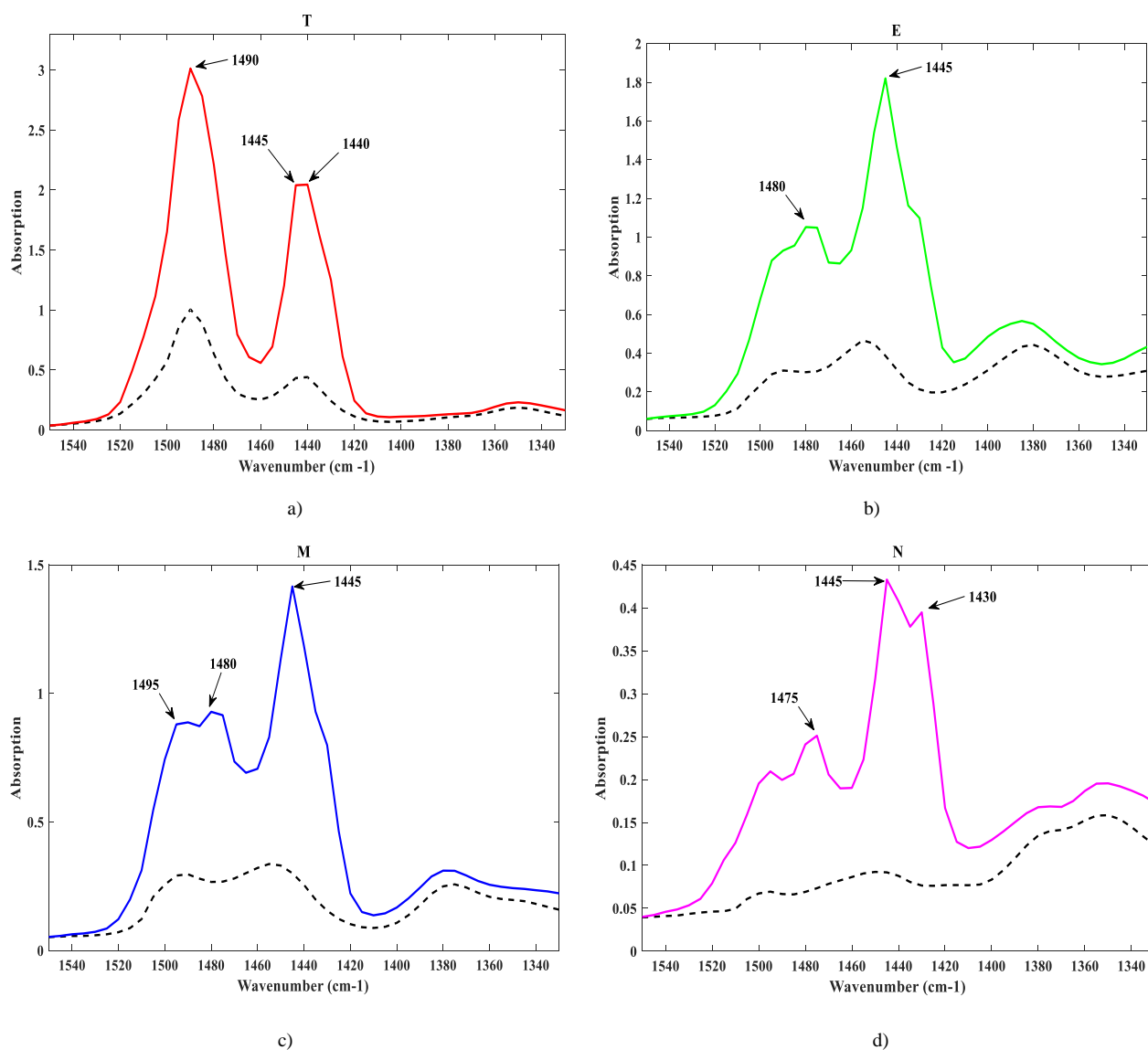


Fig. 2. Mean spectra of: a) hallucinogenic amphetamines (class code T); b) ephedrine (class code E); c) stimulant amphetamines (class code M); d) non-amphetamines (class code N). - - - - - initial spectrum; ——— spectrum preprocessed with the  $w_{TE}$  selective amplifier.

The database formed with the processed spectra has been subjected to PCA, in order to perform an exploratory analysis. The number of principal components (PCs) needed to model the targeted classes of drugs of abuse has been established based on the dynamics of the cumulated explained variance, which indicates that the first two PCs are enough for this purpose (see Fig. 3).

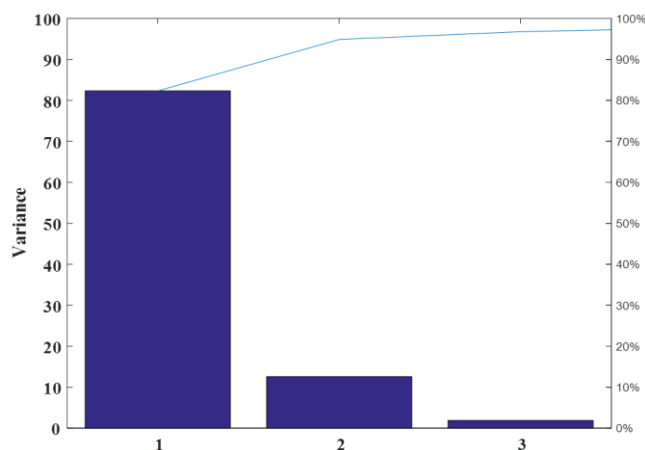


Fig. 3. Explained variance obtained for the spectra recorded between 1550 and 1330 cm<sup>-1</sup> and processed with the  $w_{TE}$  feature weight.

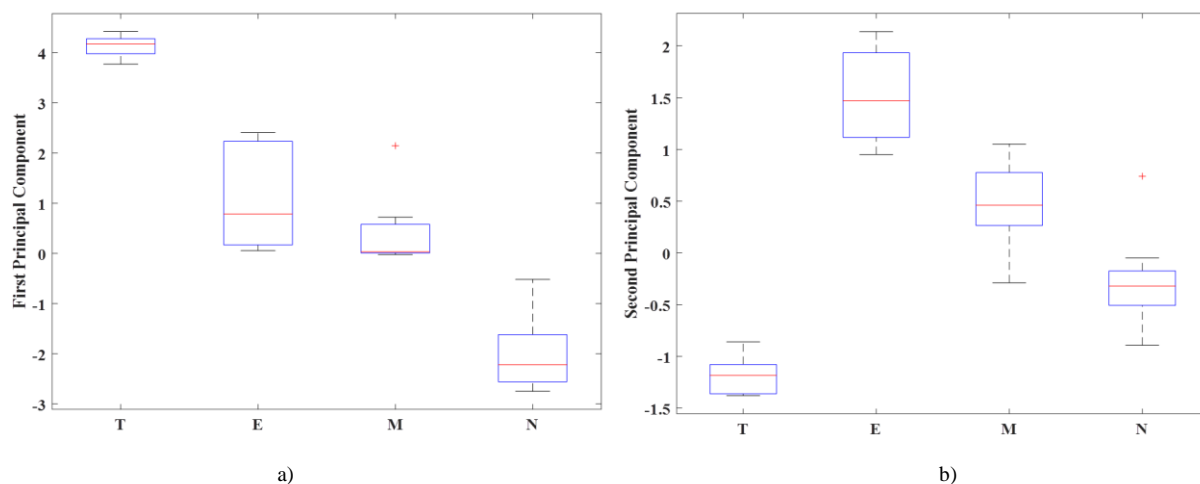


Fig. 4. Statistical analysis of the PCA scores of hallucinogenic amphetamines (T), ephedrine (E), stimulant amphetamines (M) and negatives (N): a) PC1 scores; b) PC2 scores.

The scores specific to each modeled class of compounds have been assessed by using statistical box plots, which are presented in Fig. 4. They indicate that PC1 is mainly discriminating the hallucinogens (T) and the negatives (N) from the stimulant phenethylamines (M and E). However, the PC1 scores of AMP and EPH analogues are relatively similar. On the other hand, the PC2 scores are clearly distinguishing between the latter two groups of synthetic drugs.

These aspects may also be observed in the PC1 vs. PC2 score plot presented in Fig. 5. The MDA analogues (T) are forming a very well-defined and dense cluster found in quadrant IV. They are the only compounds characterized by large positive PC1 and negative PC2 scores. With the exception of N33 (dextromoramide), the cluster formed by the negatives is located in quadrant III, these substances being characterized by large negative PC1 and PC2 scores. On the other hand, the points associated to the stimulant amphetamines (M), as well as those specific to the ephedrine (E) are quite scattered. The cluster formed by the ephedrine is found in quadrant I and may be distinguished from the M cluster based on the PC2 scores. All EPH isomers and analogues have positive PC2 scores that are typically larger than those of the stimulant amphetamines (M). With the exception of M17 ( $\beta$ -phenylethylamine), all the AMP analogues have small positive PC1 and PC2 scores.

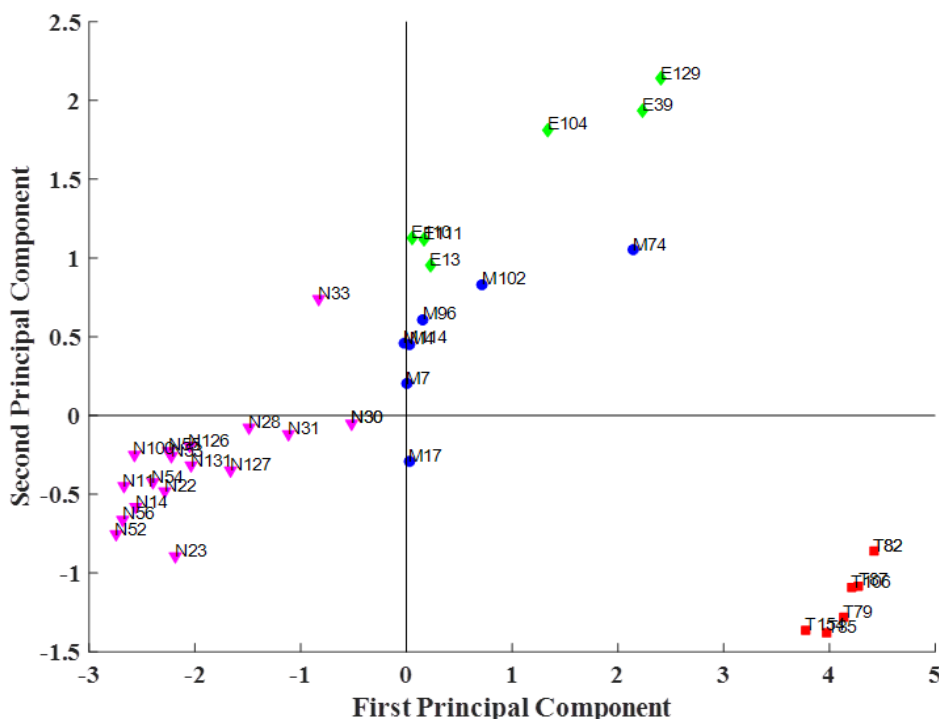


Fig. 5. PC1 vs. PC2 score plot obtained for the  $w_{TE}$  processed spectra of hallucinogenic amphetamines (T), ephedrine (E), stimulant amphetamines (M) and negatives (N).

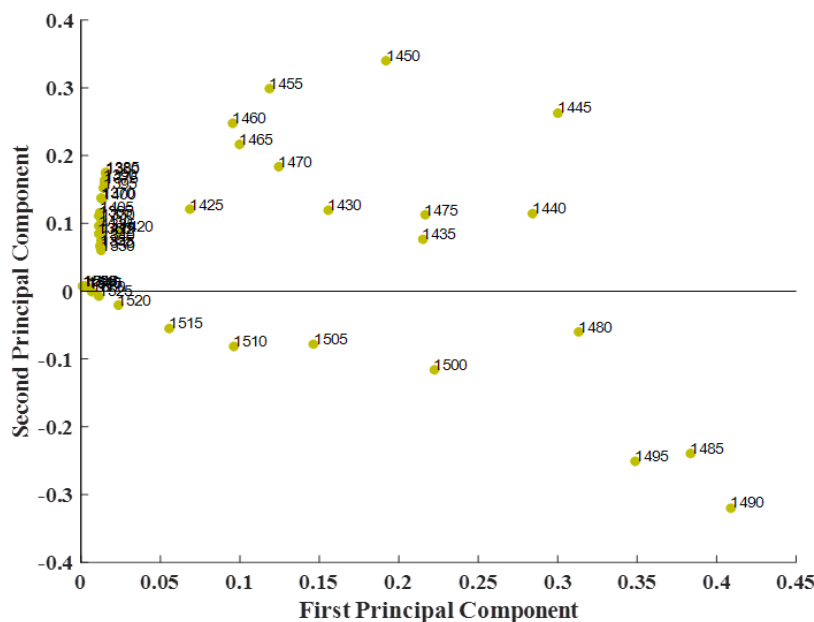


Fig. 6. PC1 vs. PC2 loading plot obtained for the  $w_{TE}$  processed spectra of hallucinogenic amphetamines (T), ephedrine (E), stimulant amphetamines (M) and negatives (N).

The associated loading plot, presented in Fig. 6, may help us identify the main absorptions that are responsible for the formation of each of the four clusters. The larger the weight of a variable (wavenumber), the more important it is for clustering a given class of modeled compounds. The plot indicates that the hallucinogens (T) form such a well-defined cluster due to their strong and very stable absorption band found at  $1490\text{ cm}^{-1}$  (see also Fig. 2a) (Praisler et al., 2000a), (Praisler et al., 2000b). As all the variables between  $1520$  and  $1480\text{ cm}^{-1}$  are also contributing to the formation of this dense cluster, we may conclude that the shape of the left wing of the  $1490\text{ cm}^{-1}$  band is also a spectral feature used for the recognition of MDA analogues.

The absorptions between  $1425$  and  $1475\text{ cm}^{-1}$  are contributing to the formation of the M and E clusters, being responsible for the large positive PC1 and PC2 scores of these compounds. The absorptions around  $1380\text{ cm}^{-1}$  are mainly responsible for distinguishing ephedrine from AMP and its analogues. Both classes of drugs have a specific absorption band at this wavenumber (Praisler et al., 2002). Fig. 6 corroborated with Fig. 2b and 2c indicate that the discrimination relies on the intensity of this band. We may conclude that the ephedrine (E) has larger positive PC2 scores because, in their case, the  $1380\text{ cm}^{-1}$  absorption band is typically stronger than in the case of stimulant amphetamines (M).

#### 4. Conclusions

The application was designed to operate a new portable spectrometer, which is equipped with a QCL that emits between  $1550$  and  $1330\text{ cm}^{-1}$  (UT7). The results indicate that the system is a fast and efficient forensic tool, as it detects automatically all the substances having a molecular structure similar (not only identical) to the modeled classes of compounds, i.e. hallucinogenic amphetamines, stimulant amphetamines and their main precursors, the ephedrine.

The main challenge in building this application was to obtain, despite the narrowness of the spectral domain specific to the UT7 laser source, a correct classification rate similar to that obtained with the full infrared GC-FTIR spectra, which are recorded between  $4000$  and  $600\text{ cm}^{-1}$ . The results indicate that although the balance between the number of variables (absorbances) and the number of objects (compounds) is better in the case of the laser spectrometer than in the case of the GC-FTIR instruments providing the full infrared spectrum, the overall accuracy of the system is slightly lower in the former than in the latter case (Praisler et al., 2000), (Praisler et al., 2002).

More specifically, the closeness of the clusters formed by the stimulant amphetamines (M) and ephedrine (E) revealed by the PCA score plot indicates that some misclassifications between these two classes of compounds are to be expected. This behavior is due to the extreme similarity of the molecular structures (and hence of the infrared spectra) of these two classes of compounds. For example, EPH has the MAMP molecular structure with a  $-\text{OH}$  group at the  $\beta$  position. This similarity also explains the fact that both classes of drugs share the same pharmacological activity, i.e. they are all CNS stimulants (Karch, 2007).

Nevertheless, this weakness is not essential: the laser spectrometer is designed to scan the suspect samples for controlled substances, i.e. to assign the class identity of all the compounds similar to the modeled ones. Once a sample is found as a T, M or E positive, it is sent to the laboratory for individual identification, based on its full GC-FTIR and GC-MS spectra. Hence, as long as the potential misclassifications may appear only between classes of controlled substances, the system is perfectly acceptable from a forensic point of view.

What is essential is that no positive (T, M or E) is misclassified as a negative (N). From this point of view, the accuracy of the system is similar to that of the applications processing the full infrared spectra.

The score and loading plots confirm that processing the spectra with the feature weight  $w_{TE}$  is crucial. This function manages to identify and to emphasize the most relevant absorptions. These are characterized by the best stability, not only from the point of view of their position and intensity, but also of their shape. Interestingly, the absorptions bands found by the  $w_{TE}$  feature weight to have the most important modeling and discrimination power are not necessarily the strongest ones. Medium or weak absorption bands may very well be the most relevant for distinguishing among the modeled classes of compounds, if they are relatively stable and specific to one or more of these classes.

In conclusion, the exploratory analysis performed in this study encourages further studies aiming to the development of intelligent systems based on more complex classification techniques.

## Acknowledgements

Part of the research has been funded by EC under the grant agreement n° FP7-SEC-2009-242309 DIRAC. The work of Stefanut Ciochina has been funded by the Romanian Ministry of European Funds within the POSDRU/107/1.5/S/76822 project. The authors are grateful for the financial support.

## References

- Ciochina, S., M. Praisler M., Negoita, C., Cluster Analysis Evaluating the Automated Detection of Drugs of Abuse with a New Hollow Fiber based Quantum Cascade Laser Infrared Spectrometer, 2017 *E-Health and Bioengineering Conference EHB*, pp. 237-240, Sinaia, Romania, (2017).
- Herbst, J., Scherer, B., Ruf, A., Erb, J., Lambrecht, A., Hollow fiber based quantum cascade laser spectrometer for fast and sensitive drug identification, *Proceedings of SPIE - The International Society for Optical Engineering SPIE* 8268, 82681Q (2012).
- Jolliffe, T., *Principal Component Analysis*, 2<sup>nd</sup> edition, Springer, (2002).
- Karch, S., *Drug of Abuse Handbook*, 2<sup>nd</sup> edition, CRC Press, (2007).
- Laing, R., *Hallucinogens. A Forensic Drug Handbook*, Academic Press, (2003).
- Mengali, S., Liberatore, N., Luciani, D., Viola, R., Cardinali, G.C., Elmi, I., Poggi, A., Zampolli, S., Biavardi, E., Dalcanele, E., Bonadio, F., Delemont, O., Esseiva, P., Romolo, F.S., Rapid screening and identification of illicit drugs by IR absorption spectroscopy and gas chromatography, *Proceedings of SPIE - Quantum Sensing and Nanophotonic Devices X*, 86312F (2013).
- Momaya, A., Fawal, M., Estes, R., Performance-Enhancing Substances in Sports: A Review of the Literature, *Sports Medicine*, Vol. 45, pp. 517-531, (2015).
- Praisler, M., Ciochina, S., Coman, M., Hunting for Illicit Psychoactive Substances and Precursors: a Multivariate Approach, in Kloetzer, M; Ferariu, L. (Eds), 2017 *21st International Conference On System Theory, Control And Computing (ICSTCC)*, Book Series: International Conference on System Theory Control and Computing, pp. 248-253, Article number 8107042, Sinaia, Romania, (2017).
- Praisler, M., Ciochina, S., Global clustering quality coefficient assessing the efficiency of PCA class identity assignment, *Journal of Analytical Methods in Chemistry*, Vol. 2014, Article ID 342497, (2014).
- Praisler, M., Van Bocxlaer, J., De Leenheer, A., Massart, D.L., Automated recognition of ergogenic aids using Soft Independent Modeling of Class Analogy (SIMCA), *Turkish Journal of Chemistry*, Vol. 26, pp. 45-58, (2002).
- Praisler, M., Dirinck, I., Van Bocxlaer, J., De Leenheer, A., Massart, D.L., *Exploratory analysis for the automated identification of amphetamines from vapour-phase FTIR spectra*, *Analytica Chimica Acta*, Vol. 404, pp. 303- 317, (2000).
- Praisler, M., Dirinck, I., Van Bocxlaer, J., De Leenheer, A., Massart, D. L., Identification of novel illicit amphetamines from vapor-phase FTIR spectra - a chemometrical solution, *Talanta*, Vol. 53, pp. 155-170, (2000).
- European Monitoring Centre for Drugs and Drug Addiction (EMCDDA), *Drug supply reduction: an overview of policies and measures* (2017).
- United Nations Office on Drugs and Crime (UNODC), *World Drug Report 2017, Part 4: Market analysis of synthetic drugs: Amphetamine-type stimulants, new psychoactive substances*, United Nations, (2017).

# Scanning for illicit psychoactive drugs based on pattern recognition

Stefanut Ciochina<sup>a</sup>, Mirela Praisler<sup>a\*</sup>, Marian Coman<sup>a</sup>

<sup>a</sup>“Dunarea de Jos” University of Galati, 47 Domneasca Str., Galati 800008, Romania

---

## Abstract

We are presenting an artificial intelligence application able to perform, *in-situ*, the automatic recognition of illicit phenethylamines. Official statistics indicate that these drugs are increasingly abused worldwide as recreational drugs, for their stimulant or hallucinogenic effect on the central nervous system. The spectra of a series of known illicit amphetamines have been recorded, with a resolution of 5 cm<sup>-1</sup>, with a portable spectrometer equipped with a quantum cascade laser operating in the 1550 - 1330 cm<sup>-1</sup> infrared spectral domain. The spectra have been pre-processed by using a *wTE* Fisher function, which was defined based on structure - activity relationships. As the number of available compounds is relatively small, a data dimensionality reduction was performed by using Principal Component Analysis (PCA). The cluster overlap was estimated based on confidence intervals determined for each of the main principal components. The 3D score plot and associated loading plots have been analyzed in order to assess the quality of the identifiable clusters. Then, a new database, consisting of the PCA scores, was subjected to Hierarchical Cluster Analysis (HCA). The recommended number of clusters (as measured by the Silhouette index), the clustering tree built by using agglomerative clustering and the corresponding cophenetic correlation coefficient have been analyzed for an increasing number of principal components. The best correct classification rates have been obtained for four clusters, i.e. stimulant amphetamines, hallucinogenic amphetamines, ephedrine and negatives. Hence, combining these two pattern recognition methods (PCA and HCA) leads to an efficient forensic tool scanning for illicit psychoactive drugs. The system may successfully reveal not only the class identity of unknowns, but also their most likely pharmacological effect.

**Keywords:** psychoactive drugs; pattern recognition; infrared laser spectrometry.

---

## 1. Introduction

During the last decade, an alarming increase of the number of clandestine laboratories producing synthetic drugs of abuse, especially amphetamine analogues, have been noticed worldwide, especially in Eastern Europe (UNODC, 2017a), (UNODC, 2017b). This finding has emphasized the urgent need for capacity-building and better forensic technical assistance. Consequently, the European Union (EU) has decided to fund the development of new and more accurate instruments that might help the police and customs officers to detect illicit substances more efficiently (EMCDDA, 2017). The prototype of such an instrument, i.e. a portable Gas Chromatography – Infrared Absorption Spectrometer (GC-IRAS) that uses a quantum cascade laser (QCL) as source of radiation, has been developed within the EU funded DIRAC project. This instrument was expected to be able to perform a fast *in situ* detection of amphetamine-type stimulants (ATS) and of their main precursors (Herbst et al., 2012), (Mengali et al., 2013), (Praisler et al., 2014a).

We should underline that the instrument is capable to analyze mixtures, the GC module ensuring the separation of their components. This means that, in the case of illicit tablets, besides the major active ingredients and adulterants, the excipients (diluents, binders, disintegrators, lubricants, damping agents, drying agents) and other products such as dyes, aromas and sweeteners may also be identified. This aspect is very important, because the ingredients used in formulations vary considerably from one manufacturer to another and thus the origin of the illicit tablets can be traced (Karch, 2007). Another important feature of the portable spectrometer is that it can analyze not only tablets and powders, but also liquids. Hence, it may be also used by the authorities for monitoring real-time data on geographical and temporal trends in illicit drug use based on wastewater analysis (EMCDDA, 2018).

In this paper we are presenting an artificial intelligence application that was built to operate this GC-IRAS portable spectrometer. The application assigns the class identity of hallucinogenic and stimulant amphetamines, as well as of ephedrine, which are their main precursors (Karch, 2007), (Laing, 2003), (Momaya et al., 2015).

---

\* Corresponding author. Tel.: +4-072-299-5869; fax: +4-023-631-9329.  
E-mail address: Mirela.Praisler@ugal.ro.

The class membership is established subjecting the spectra to Principal Component Analysis (PCA) and then to Hierarchical Cluster Analysis (HCA). The results indicate that the system is characterized by correct classification rates similar to those obtained with the full infrared spectra (recorded between 4000 and 600  $\text{cm}^{-1}$ ).

## 2. Experimental part

A former study has indicated that the best results may be obtained with the spectra recorded with a quantum cascade laser (QCL) emitting in the 1550 - 1330  $\text{cm}^{-1}$  spectral window (UT7) (Praisler and Ciochina, 2013). Hence, a first spectral database has been built with the spectra recorded in this spectral domain, with a 5  $\text{cm}^{-1}$  resolution. This database consists of the vibrational spectra of seven stimulant amphetamines, six hallucinogenic amphetamines and six ephedrines. The class of stimulant amphetamines, further referred to as class M, includes amphetamine (AMP) and its main analogues MAMP, EAMP, PAMP, APEA, MAPEA and BPEA (Karch, 2007), (UNODC, 2017b). The class of hallucinogenic amphetamines (class T) contains the spectra of 3,4-methylenedioxymphetamine (MDA) and of its main analogues MDMA, MDEA, N-OH-MDEA, BDB and MBDB (Laing, 2003), (UNODC, 2017b). The ephedrines are represented by ephedrine (EPH) and its main isomers and analogues, i.e. pseudoephedrine, norephedrine, norpseudoephedrine, N-methylephedrine and benzylephedrine (Karch, 2007), (Momaya et al., 2015). The database also contains the spectra of seventeen negatives, representing a large variety of toxicological concern (Praisler et al., 2014a). The natural coherence and the global quality of the clusters are often enhanced significantly by spectra processing (Praisler and Ciochina, 2014b). Former tests have indicated that this is especially true in the case when only a limited part of the full infrared spectrum is taken into account (Ciochina et al., 2017). Hence, the spectra included in the database have been processed with a  $w_{TE}$  feature weight, which was obtained by using the Fisher function. To define and compute  $w_{TE}$ , the spectra of T and E compounds have been included in class I, and those of the M and N compounds in class II.

The dimensionality of the data was then reduced by subjecting the  $w_{TE}$  processed spectra to Principal Component Analysis (PCA) (Jolliffe, 2002). The cluster overlap was estimated based on confidence intervals determined for each of the main principal components. The 3D score plot and associated loading plots have been analyzed in order to assess the quality of the identifiable clusters. Then, a new database, consisting of the PCA scores, was subjected to Hierarchical Cluster Analysis (HCA) L. (Kaufman and P.J. Rousseeuw, 2005). More specifically, clustering trees have been built based on the scores computed for an increasing number of principal components (PCs) and hierarchical agglomerative clustering algorithm. The number of clusters that may be best distinguished has been identified quantitatively, by using the average Silhouette index (Starczewski and Krzyżak, 2015). The cophenetic correlation coefficient has been used in order to assess which of these dendrograms preserves best the distances between the original unmodeled objects.

The correct classification rates have been compared, in order to identify the most efficient computational architecture. The efficiency of the best performing system has also been compared with that obtained for systems designed to assign the same class identities based on the full infrared spectrum and pattern recognition methods (Praisler et al., 2002), (Praisler et al., 2000a).

## 3. Results and discussion

The  $w_{TE}$  processed spectra have been explored by using PCA. In order to determine the number of PCs needed to model the targeted classes of drugs of abuse, the eigenvalues and the explained variance have been calculated. The results presented in Table 1 indicate that the first three PCs are enough for this purpose, as they are cumulating an explained variance of 96.77% (see Fig. 3).

Table 1. Eigenvalues and explained variance determined with the  $w_{TE}$  processed spectra of stimulant and hallucinogenic amphetamines and of ephedrines

Eigenvalue	Explained variance (%)	Cumulated explained variance (%)
5,6222	82.3366	82.3366
0,8571	12.5527	94.8893
0,1287	1.8844	<b>96.7737</b>

The mean scores and the confidence intervals calculated for PC1 indicates that this PC, which is associated with most of the explained variance (82.34 % out of 96.77%), is mainly discriminating the hallucinogenic amphetamines (T) and the negatives (N) from the other two classes of modeled compounds, i.e. stimulant amphetamines (M) and ephedrines (E) (see Fig.1). The PC2 scores are strengthening this discrimination. In addition, although PC2 accounts for only 12.55% of the explained variance, it distinguishes between the latter two modeled classes of controlled drugs. This behavior is remarkable, as the compounds belonging to these two classes of stimulant phenethylamines (M and E) have a very similar molecular structure (see Fig. 2). The PC3 scores do not seem to have a specific role.

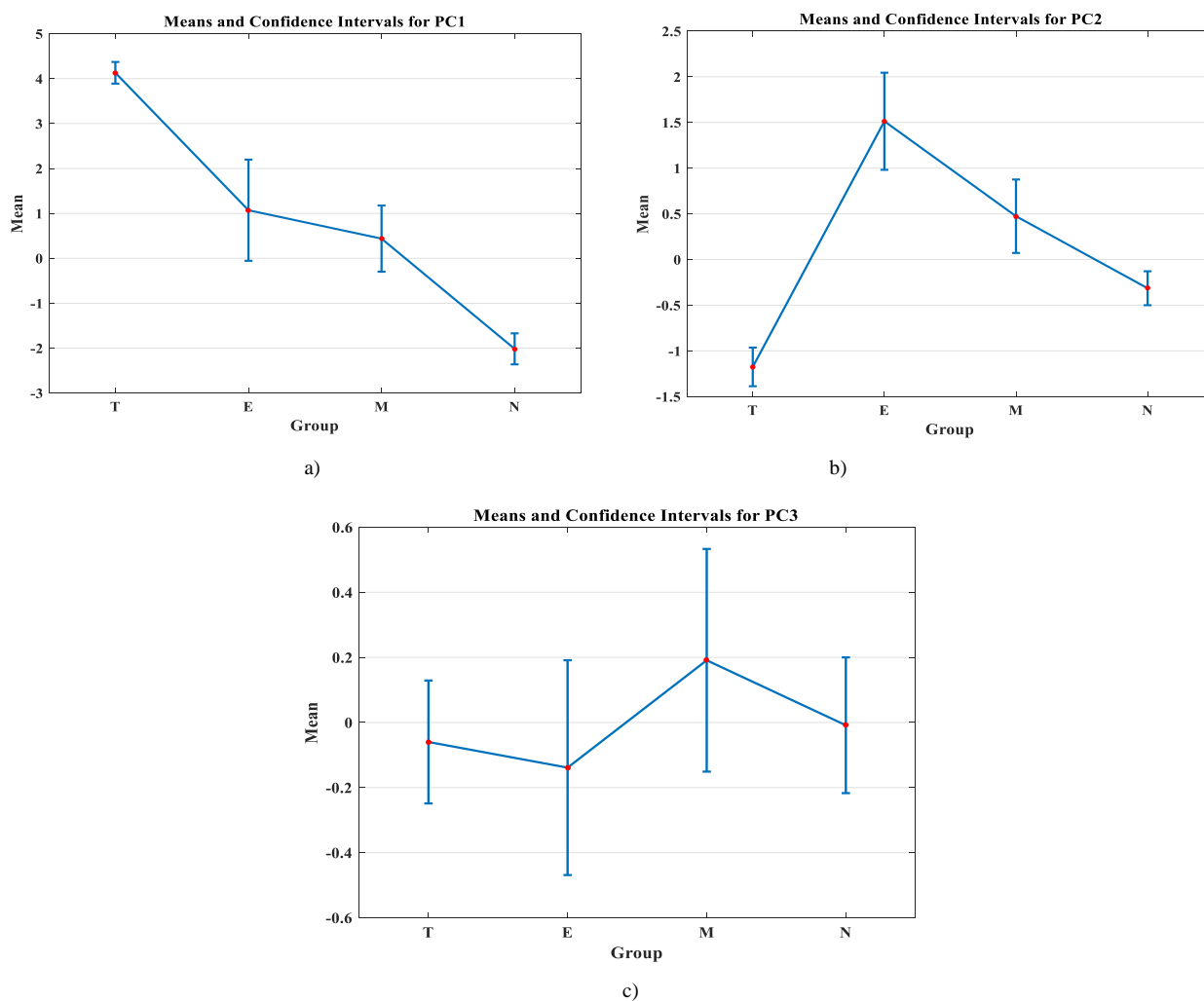


Fig. 1. Confidence intervals associated to the PCA scores determined based on the  $w_{TE}$  processed spectra of hallucinogenic amphetamines (class code T), ephedrines (E), stimulant amphetamines (M) and negatives (N); a) PC1; b) PC2; c) PC3

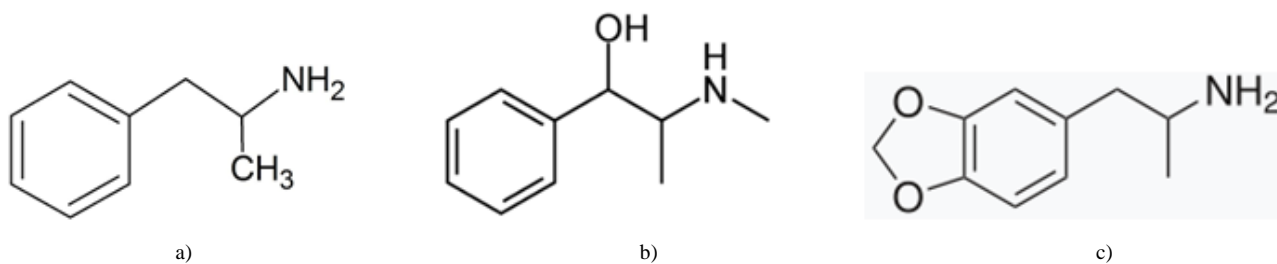


Fig. 2. Molecular structure of the parent compounds of the modeled classes of illicit drugs: a) amphetamine (AMP); b) ephedrine (EPH); c) 3,4-methylenedioxamphetamine (MDA)

The 3D score plot and the associated loading plots are presented in Fig. 3 and Fig. 4. The most important absorptions, which are characterized by the largest (positive) PC1 loadings, leading to the most specific discriminations ensured by the PC1 scores (the T and N clusters from the M and E clusters) are found around 1490 and 1445  $\text{cm}^{-1}$ . They are highly specific to the hallucinogenic amphetamines, which are displaying very strong and stable absorption bands at these wavenumbers (Praisler et al., 2000b).



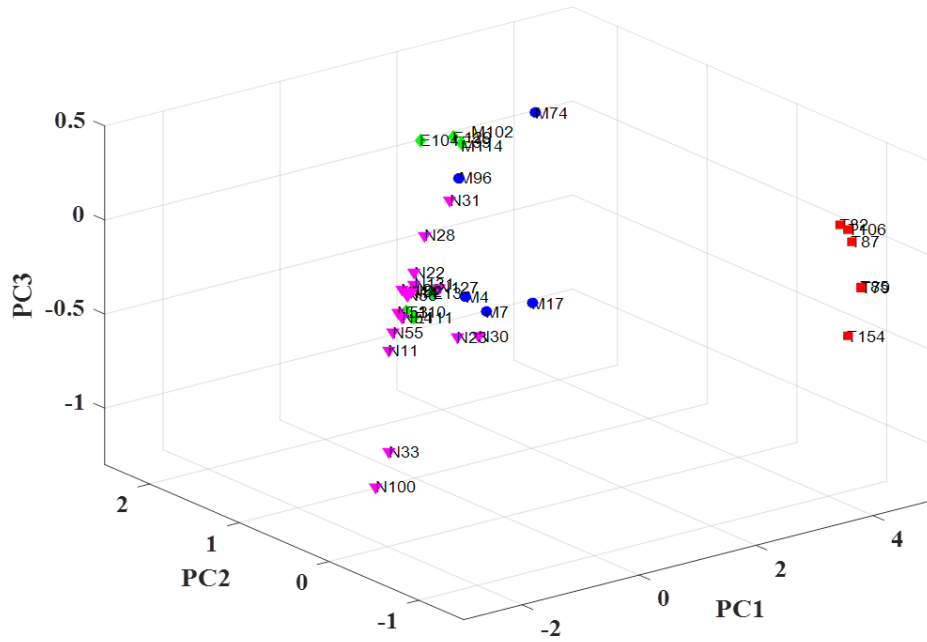


Fig. 3. 3D score plot discriminating the targeted psychoactive substances: stimulant amphetamines (M, blue dots), hallucinogenic amphetamines (T, red dots), ephedrines (E, green dots) and negatives (N – purple dots).

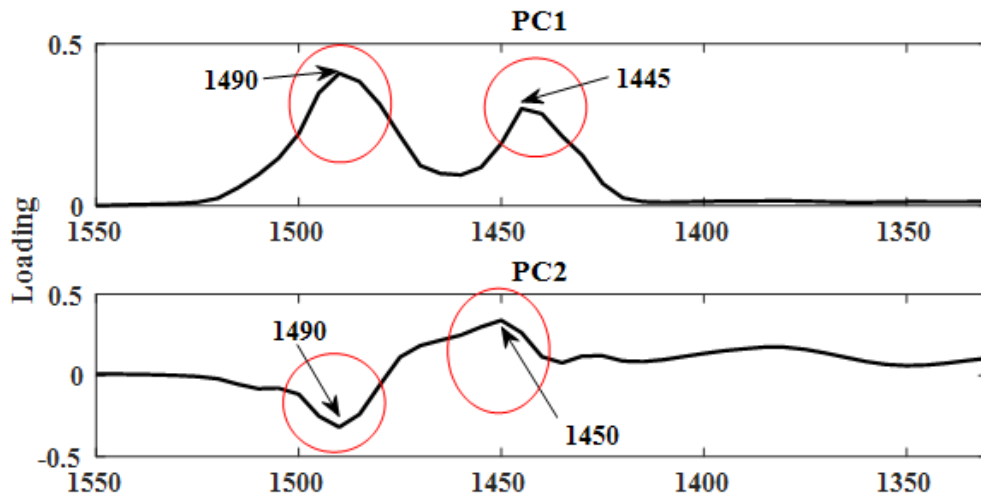


Fig. 4. PCA loading plots obtained for the  $w_{TE}$  processed spectra of stimulant amphetamines, hallucinogenic amphetamines, ephedrines and negatives

These absorptions are also characterized by large (negative or positive) PC2 loadings, which is consistent with the important role played by the PC2 scores in distinguishing the T and N clusters from the M and E clusters. Besides these absorptions, the other absorptions between 1475 and 1425  $\text{cm}^{-1}$  have also significant positive loadings. These variables are contributing to the discrimination between stimulant amphetamines (M) and ephedrines (E) (Praisler et al., 2000b).

A first quantitative assessment of the number of clusters that may be best distinguished in the score plots has been made from the point of view of the consistency within the clusters of data, based on the average Silhouette index. This assessment has been performed for an increasing number of PCs, i.e. for the clusters identifiable based on the scores of PC1, then by using the PC1 and PC2 scores, and finally based on the (PC1, PC2, PC3) scores. In all cases, the index values have indicated that the best results may be obtained with four clusters, i.e. stimulant amphetamines (M), hallucinogenic amphetamines (T), ephedrines (E) and negatives (N). The highest (and very similar) values have been obtained for the average Silhouette index in the case of one (PC1) and of two (PC1 and PC2) PCs (see Fig. 5), i.e. 0.8779 and 0.8671 respectively.

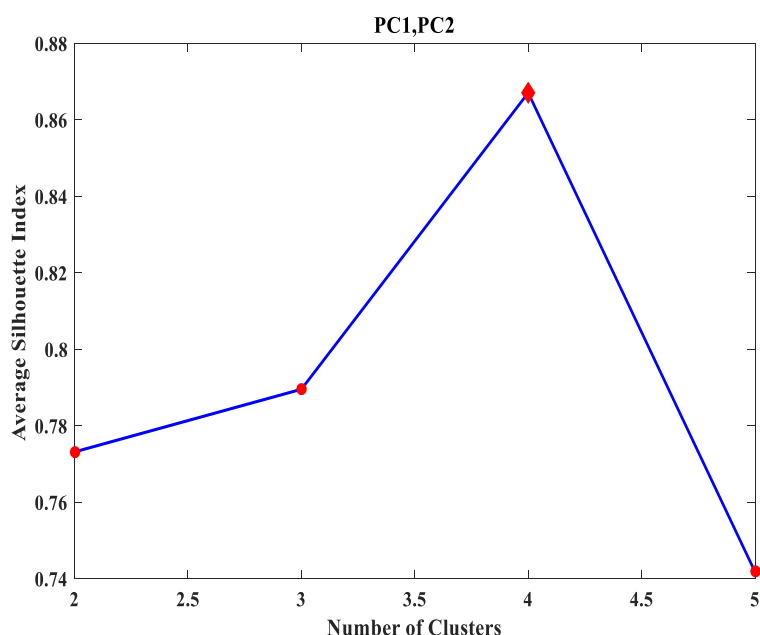


Fig. 4. Average Silhouette index obtained based on the PC1 and PC2 scores obtained for the  $w_{TE}$  processed spectra of the targeted compounds

Hence, clustering trees have been built for these two cases, by using HCA based on the agglomerative clustering algorithm. They have been evaluated based on the cophenetic correlation coefficient  $c$ , which assesses how well a dendrogram maintains the distances between the unmodeled objects. The best (and very similar) values have been obtained for the clustering trees built with the (PC1, PC2) scores and with the (PC1, PC2, PC3) scores, i.e.  $c = 0.8755$  and  $c = 0.8759$  respectively. Taking into account these results and the correct classification rates, we have concluded that the best computational approach is to combine HCA with PCA, the input for the hierarchical agglomerative clustering algorithm being the PC1 and PC2 scores.

The dendrogram obtained in this case is presented in Fig. 6. It indicates that the main characteristics of this class identity assignment system are the remarkable sensitivity and selectivity in detecting the class formed by the amphetamines with the highest toxicity, i.e. the hallucinogens (T). Another very important characteristic is the selectivity of the system from the point of view of the negatives: no positive compound (T, M, E) is (mis)classified as a negative. A lower but quite acceptable accuracy is obtained in the case of the M and E compounds, due to the extremely high similarity between the molecular structures, and consequently of their infrared spectra, of these two classes of stimulant phenethylamines.

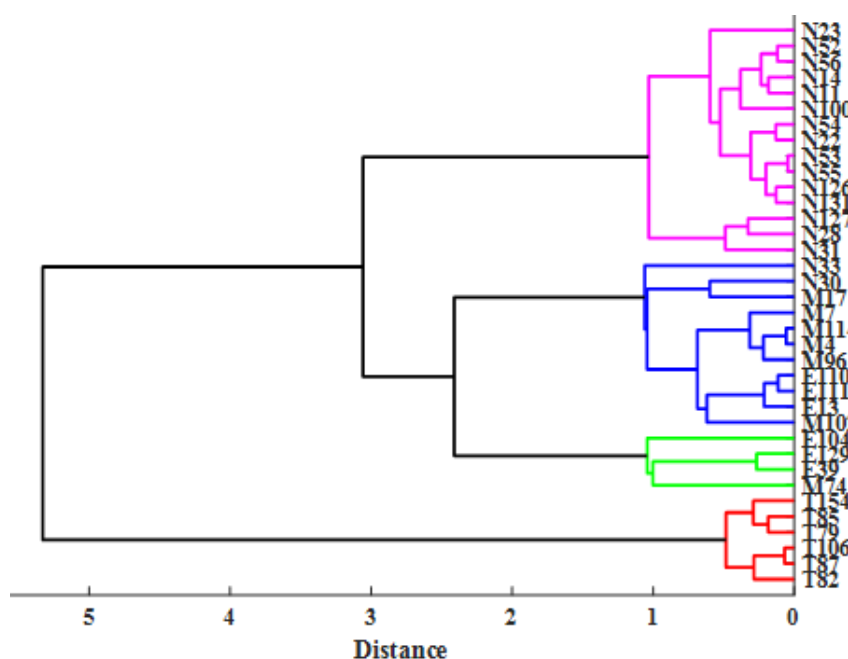


Fig. 5. HCA clustering tree built with the PC1 and PC2 scores specific to the  $w_{TE}$  processed spectra of the modeled illicit drugs

#### 4. Conclusions

The results indicate that combining PCA and HCA leads to an efficient forensic artificial intelligence application. Although its accuracy in distinguishing stimulant amphetamines from ephedrine, which are their main precursors, is lower than in the case of the systems assigning the class identity based on the full infrared spectrum ( $4000 - 600 \text{ cm}^{-1}$ ), the system meets the mandatory requirements of a screening tool. This is a compromise that must be made in order to decrease the size of the portable spectrometer by replacing the traditional IR source of radiation, which is quite voluminous, with a QCL.

This compromise is quite acceptable, if we keep in mind that the system is only expected to screen for the modeled classes of drugs of abuse, and not to identify their individual nature. What is essential is that no positive is misclassified as a negative, meaning that all the illicit samples will be detected *in situ* as positives. Hence, the suspect substance will be taken into custody and sent for individual identification in laboratory conditions (based on several analytical methods, such as the full vibrational spectra).

#### References

- Ciochina, S., Praisler, M., Coman, M., Hierarchical Cluster Analysis Applied for the Automated Recognition of Psychoactive Substances and of Their Main Precursors, *2017 5th International Symposium on Electrical and Electronics Engineering (ISEEE)*, 20-22 October, Galati, Romania, (2017).
- Herbst, J., Scherer, B., Ruf, A., Erb, J., Lambrecht, A., Hollow fiber based quantum cascade laser spectrometer for fast and sensitive drug identification, *Proceedings of SPIE - The International Society for Optical Engineering SPIE* 8268, 82681Q, (2012).
- Jolliffe, T., *Principal Component Analysis*, 2<sup>nd</sup> edition, Springer, (2002).
- Karch, S., *Drug of Abuse Handbook*, 2<sup>nd</sup> edition, CRC Press, (2007).
- Kaufman, L., Rousseeuw, P.J., *Finding Groups in Data. An Introduction to Cluster Analysis*, Wiley, (2005).
- Laing, R., *Hallucinogens. A Forensic Drug Handbook*, Academic Press, (2003).
- Mengali, S., Liberatore, N., Luciani, D., Viola, R., Cardinali, G.C., Elmi, I., Poggi, A., Zampolli, S., Biavardi, E., Dalcanele, E., Bonadio, F., Delemont, O., Esseiva, P., Romolo, F.S., Rapid screening and identification of illicit drugs by IR absorption spectroscopy and gas chromatography, *Proceedings of SPIE - Quantum Sensing and Nanophotonic Devices X*, 86312F, (2013).
- Momaya, A., Fawal, M., Estes, R., Performance-Enhancing Substances in Sports: A Review of the Literature, *Sports Medicine*, Vol. 45, pp. 517-531, (2015).
- Praisler, M., Ciochina, S., Stoica, A., Dumitriu, L., Signal selective amplification: A solution for an improved detection of amphetamines with QCL equipped portable GC-IRAS spectrometers, *2014 18th International Conference on System Theory Control and Computing (ICSTCC)*, Sinaia, Romania, (2014).
- Praisler, M., Ciochina, S., Global clustering quality coefficient assessing the efficiency of PCA class identity assignment, *Journal of Analytical Methods in Chemistry*, Vol. 2014, Article ID 342497, (2014).
- Praisler, M., Ciochina, S., PCA Evaluation of Quantum Cascade Lasers as Radiation Sources for Portable IRAS Systems Detecting Amphetamines, *Proceedings of the IEEE International Conference on e-Health and Bioengineering -EHB 2013*, p. 1-4, Iasi, Romania, (2013).
- Praisler, M., Van Bocxlaer, J., De Leenheer, A., Massart, D.L., Automated recognition of ergogenic aids using Soft Independent Modeling of Class Analogy (SIMCA), *Turkish Journal of Chemistry*, Vol. 26, pp. 45-58, (2002).
- Praisler, M., Dirinck, I., Van Bocxlaer, J., De Leenheer, A., Massart, D.L., Exploratory analysis for the automated identification of amphetamines from vapour-phase FTIR spectra, *Analytica Chimica Acta*, Vol. 404, pp. 303-317, (2000).
- Praisler, M., Dirinck, I., Van Bocxlaer, J., De Leenheer, A., Massart, D. L., Identification of novel illicit amphetamines from vapor-phase FTIR spectra - a chemometrical solution, *Talanta*, Vol. 53, pp. 155-170, (2000).
- Starczewski A., Krzyżak, A., Performance Evaluation of the Silhouette Index, *Artificial Intelligence and Soft Computing ICAISC 2015, Lecture Notes in Computer Science*, Vol. 9120, pp. 49-58, (2015).
- European Monitoring Centre for Drugs and Drug Addiction (EMCDDA), *Drug supply reduction: an overview of policies and measures*, EMCDDA, (2017).
- European Monitoring Centre for Drugs and Drug Addiction (EMCDDA), *Wastewater analysis and drugs: a European multi-city study*, EMCDDA, (2018).
- United Nations Office on Drugs and Crime (UNODC), *World Drug Report 2017, Part 2: Global overview of drug demand and supply*, United Nations, (2017).
- United Nations Office on Drugs and Crime (UNODC), *World Drug Report 2017, Part 4: Market analysis of synthetic drugs: Amphetamine-type stimulants, new psychoactive substances*, United Nations, (2017).

## Live car traffic monitoring with Raspberry Pi hardware

Cosmin Rus<sup>a\*</sup>, Monica Leba<sup>a</sup>

<sup>a</sup>University of Petrosani, University Street 20, Petrosani 332006, Romania

---

### Abstract

This paper presents traffic management and road monitoring applications using the latest generation of IT and mobile telecommunication systems. An intelligent system with self-learning function is proposed for urban traffic junctions. This system allows automatic adjustment of green times depending on intersection traffic as well as traffic at upstream and downstream intersections. A remote road monitoring system is also introduced. This system uses modern communications equipment for periodically reading and transmitting parameters such as road temperature, humidity, wind intensity and vehicle weight. In this IoT project, we use a Raspberry Pi, a webcam and ThingSpeak to analyze traffic on a busy highway. With Simulink we design and deploy a traffic monitoring algorithm to the Raspberry Pi, and we analyze and visualize the traffic patterns using ThingSpeak, an IoT analytics platform, and MATLAB.

*Keywords:* matlab; simulink; thingspeak; urban traffic.

---

### 1. Introduction

The result of the increase in vehicle traffic has caused many problems. For example, traffic accidents, traffic congestion, air pollution caused by traffic and so on. Traffic congestion has been a significant problem. It has been widely noticed that the growth of preliminary transport infrastructure, several sidewalks and extensive roads have failed to reduce congestion in cities. As a result, many researchers have turned their attention to the Intelligent Transport System (ITS), which can use traffic flow data based on traffic monitoring at traffic junctions for congestion detection. In order to process the information and to monitor the results, in order to better understand the flow of traffic, an increasing dependence on traffic surveillance requires better detection of vehicles in an extended area. Automated detection of vehicles in video surveillance data is a very difficult issue in the eyes of computers with important practical applications such as traffic analysis and security. (Mallikarjun et al., 2017)

Vehicle detection and counting are important in calculating traffic congestion on highways. The main purpose of vehicle detection and counting in the traffic video project is to develop the methodology for automatic vehicle detection and counting on motorways. A system for efficient detection and counting of dynamic vehicles has been developed. Intelligent visual surveillance for road vehicles is a key component for the development of intelligent transport systems. The entropy masking method does not require prior knowledge of extracting road features on static images. Vehicle detection and tracking in video surveillance using segmentation with initial background decline using a morphological operator to determine the visible regions in a video frame sequence. Edges are counted showing how many areas are of a certain size, especially in the areas where the cars are located are the points and the vehicle counting in the field of traffic monitoring on highways. (Arulselvi et al., 2017)

Automated detection and tracking of video surveillance data is a very difficult issue in computer vision with important practical applications such as traffic analysis and security. Cameras are a relatively inexpensive surveillance tool. Manual review of the large amount of data it generates is often impossible. Thus, video analysis algorithms that require little or no human involvement is a good solution. Video surveillance systems focus on background modeling, vehicle classification and tracking. Increasing availability of video sensors and high-performance video processing hardware offers great possibilities to address many issues of video understanding, among which vehicle highlighting and target classification are very important. A vehicle tracking and classification system is described as one that can classify moving vehicles and further classifies vehicles in different classes. (Uke et al., 2013)

---

\* Corresponding author. Tel.: +40765744436.  
E-mail address: cosminrus@upet.ro.

## 2. Proposed system architecture

The structure of the system presented in this paper is computationally efficient and can work in real time, while maintaining very respectable detection rates. However, these types of systems contain some inevitable problems caused by obstruction of the object if a larger vehicle with a smaller, partially closed vehicle is usually considered an object, since the first plane detection methods are not projected in inherent way to segregate multiple vehicles. In another case, the appearance of a larger vehicle or a shadow of the vehicle that bypasses adjacent bands is also known to trigger false detection. Consequently, the merit of using computer vision as a surveillance tool has been limited, focusing strictly on building reliable systems over time.

The system uses an existing video sequence. The first frame is considered to be the reference framework. Subsequent frames are taken as input frames. They are compared and the background is removed. If a vehicle is present in the entry frame, it will be retained. The detected vehicle is thus tracked by various techniques, namely the adaptive base method and the block analysis method.



Fig.1 Video processing algorithm for vehicle counting

## 3. Internal detection

Open CV is an open source project, an important part of the library that implements those wrong data structures and algorithms that you can find in your open CV. Therefore, source tutorials are part of the library.

Computer vision is a rapidly growing field, partly due to both cheaper and most capable cameras, largely due to affordable processing power and partly due to the fact that vision algorithms begin to mature. Opening up the resume itself has played a role in increasing computer vision, allowing thousands of people to do more productive work in vision. Focusing on real-time vision, Open CV helps students and professionals effectively implement projects and initiate research, giving them a computer vision and a machine learning infrastructure that was previously available in just a few labs mature research. (Mallikarjun et al., 2017)

A general detection approach is to extract the characteristic regions from the video clip using a background modeling technique learned. This involves subtracting each image from the background scene. The first frame is considered the initial background and the threshold of the resultant difference image to determine the foreground image. A vehicle is a group of pixels that move in a coherent manner, either as a lighter region on a darker background or vice versa. Often, the vehicle may have the same color as the background, or may be part of it may be aging with the background, because of which vehicle detection becomes difficult. This leads to a wrong number of vehicles. (Shinde, 2015)

Detection of information can be used to refine the vehicle type and also to correct errors caused by occlusions. Once the static vehicles are recorded, the background image is low in the video frames to get the dynamic vehicles in the foreground. Post-processing is performed on top-of-the-line dynamic vehicles to reduce noise interference. (Uke, 2013)

Image segmentation is done as follows:

- Segmentation of vehicle interest regions. At this stage, regions that may contain an unknown object must be detected.
- The next step focuses on extracting appropriate features and then extracting vehicles. The primary purpose of feature extraction is to reduce data by measuring certain features that distinguish input patterns.
- Final classification. He assigns a label to a vehicle based on the information provided by his descriptors. The analysis is performed on mathematical morphology operators for segmentation of a gray image.

### a. Detection of vehicles

The adapted background surface uses the current frame and the reference image. The difference between the current frame and the reference frame exceeds the threshold is considered to be the moving vehicle. The optical flow method can detect the moving vehicle even when the camera moves, but it takes more time for its computational complexity and is very sensitive to noise. The motion area usually appears rather noisy in real images, and the optical flow estimate involves only local computing. Thus, the optical flow method can't detect the exact contour of the moving vehicle.

### a. Tracking of vehicles

Vehicle tracking involves the continuous identification of the vehicle detected in the video sequence and is achieved by specifically marking the limit around the detected vehicle. Tracking vehicles is a difficult problem. Difficulties related to vehicle tracking can occur due to steep vehicle movement, changing vehicle and scene layouts, rigid vehicle structures, vehicle and vehicle scenes, and camera shake. (Mallikarjun et al., 2017)

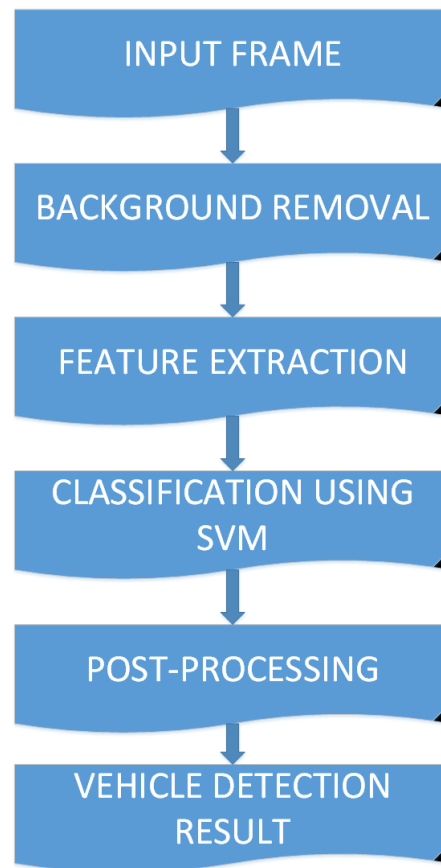


Fig. 2 The algorithm of a vehicle detection process

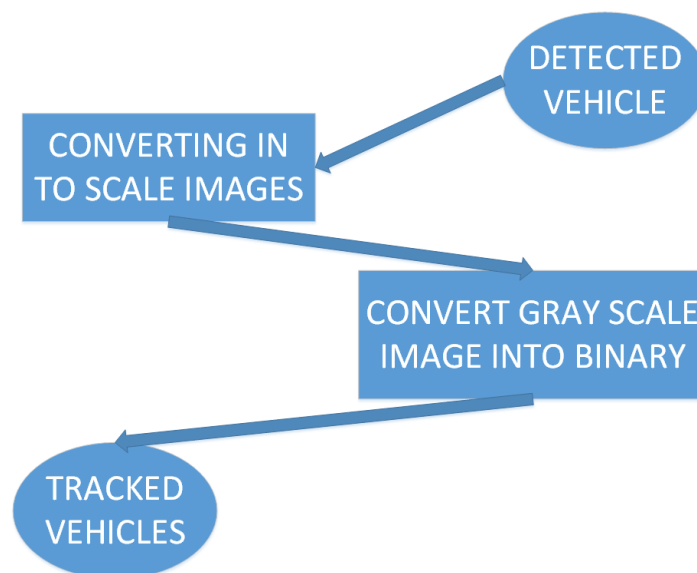


Fig. 3 The algorithm of a tracking vehicle process

#### b. Counting of vehicles

This system captures the webcam gestures that are connected to the microcontroller via the USB host and the image is processed by image processing technique. Here we use the Open CV library to detect a frontal image image using the Haar-Cascade hand detector, which will enhance interaction with the human computer. If any gesture is recognized by the camera, a rectangular box will appear on the monitor. The identified gestures are sent to Raspberry PI and we can perform TV-related functions. In this way, we implement a one-room TV control system using a gesture drawing.

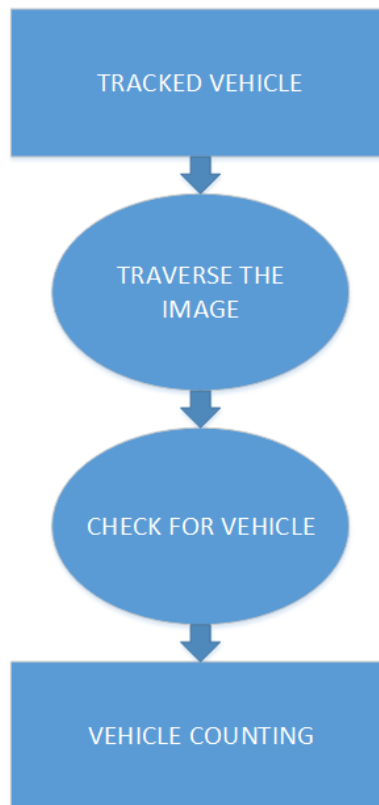


Fig. 4 The entire vehicle counting algorithm using image processing

Due to the high processing power of the data acquisition elements, this whole process of counting vehicles on a road can be done in about 0.01 seconds.

#### 4. System implementation and data analysis

In this IoT project, we use a Raspberry Pi, a webcam and ThingSpeak to analyze traffic on a busy highway. We deploy a traffic monitoring algorithm to the Raspberry Pi device, and we analyze and visualize the traffic patterns with ThingSpeak, a cloud data aggregator. This project stores data in channel 48629 on ThingSpeak.

For this project, we show how to develop analytics for the edge device and how to perform exploratory analysis on data collected on the cloud. We also illustrate a simple example of how to perform automated online analysis in the cloud. The example uses ThingSpeak and MATLAB to perform the analyses. We constructed the traffic monitor using a Raspberry Pi 3, and a USB webcam. The webcam, a Tracer HD Pro, was mounted on a flexible mini tripod. We placed the camera near a window on the 2th floor of our university building that overlooks the street. We angled the camera to have a clear view of both sides of the street. The camera was connected to one USB port of the Raspberry Pi. We then connected the Raspberry Pi to the wireless network in the building. The complete parts list is shown below.

- Raspberry Pi 3 Model B ARM v7 with 1 GB RAM
- 5 V 3 A switching Power Supply with MicroUSB cable
- Tracer HD Pro
- Monoprice flexible mini tripod
- WiFi for internet connectivity



Fig. 5 Raspberry Pi 3 connection and the webcam used



Because we did not want to send high-bandwidth video images to the cloud, we chose to detect the vehicles at the edge using the processor on the Raspberry Pi 3. We then send the count value to the data aggregator at an update rate of once every 15 seconds, the maximum data rate allowed by ThingSpeak. To develop the traffic monitoring algorithm, we used Simulink, Image Processing Toolbox, Computer Vision System Toolbox and the Simulink Support Package for Raspberry Pi Hardware. Simulink is a modeling environment that can to automatically generate code that can run on an embedded controller. In this example, Simulink generates code that runs on the Raspberry Pi 3. The Simulink model for the traffic monitoring algorithm is shown below.

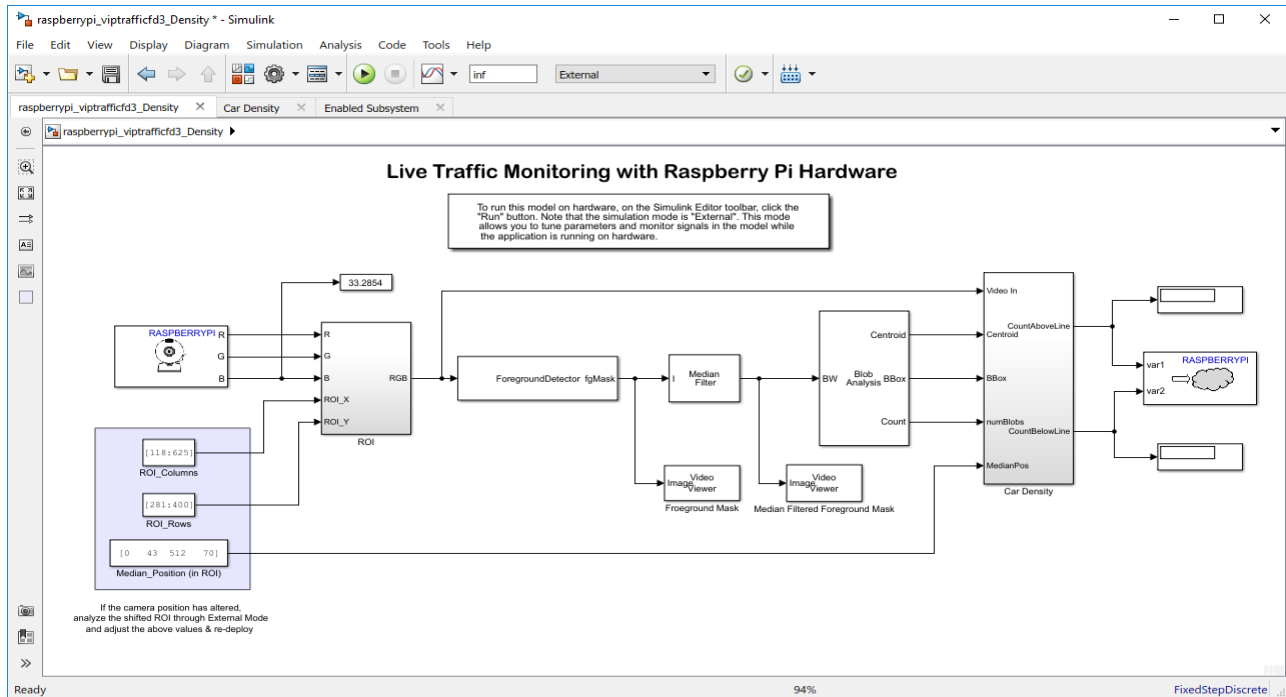


Fig. 6 Simulink traffic monitoring algorithm

To develop the algorithm, we used the external mode capability of Simulink. In this mode, Simulink gathers the video stream from the Raspberry Pi, and the user can view the video on an external monitor using the SDL Video Display block while the algorithm is running. Figure 7 shows the entire vehicle counting system using the alternative energy (solar energy in this case) as the power source of the Raspberry Pi system.

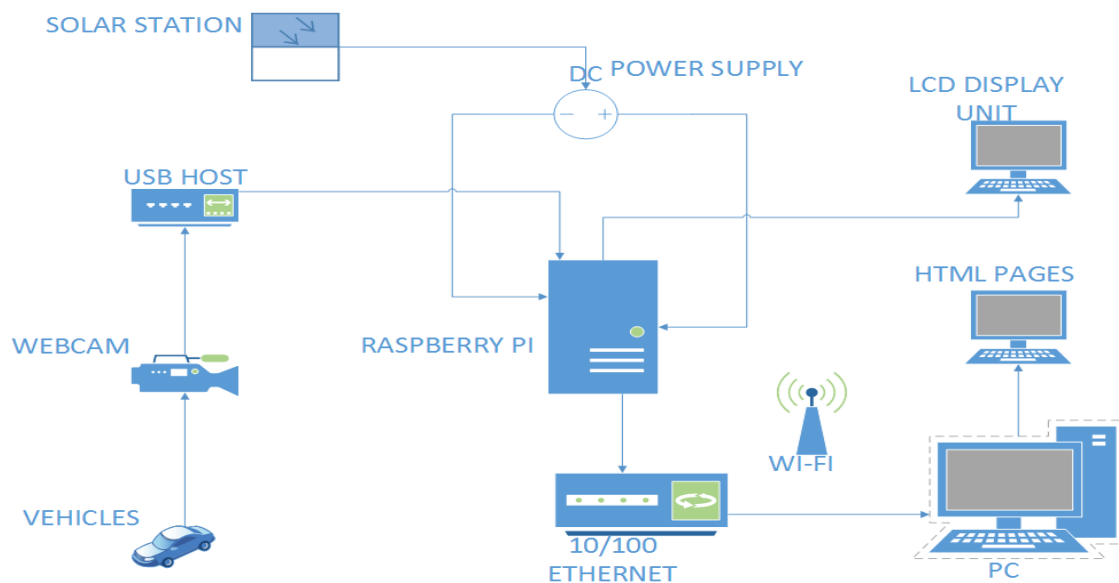


Fig. 7 Block diagram of the entire system prototype

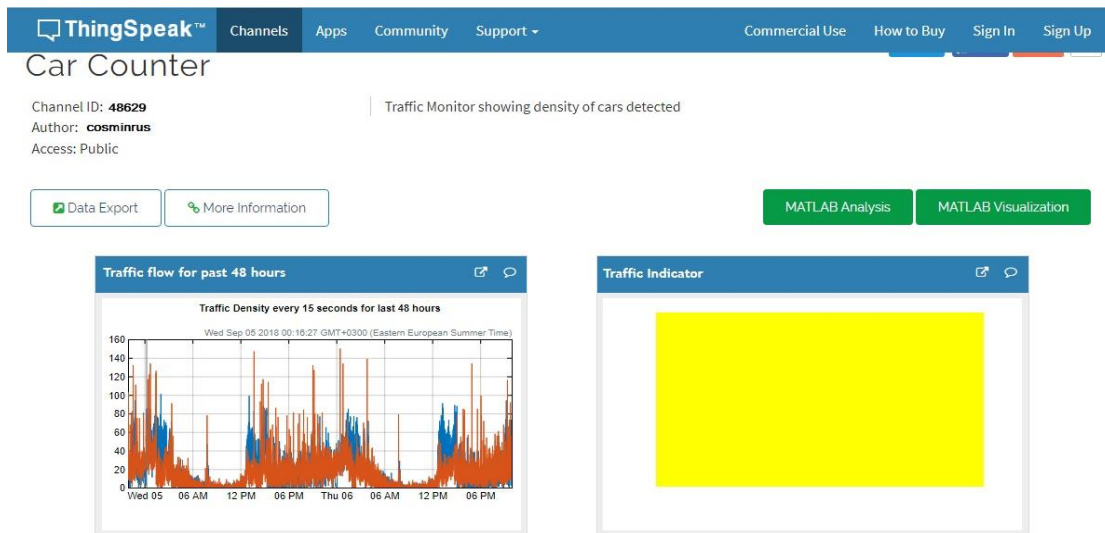


Fig. 8 ThingSpeak vehicle counter diagram

In this paper, we try to demonstrate how to develop a traffic monitoring that can be deployed onto Raspberry Pi edge node and sends data to ThingSpeak. We showed how to use MATLAB for offline analysis by retrieving data from ThingSpeak and analyzing and visualizing daily and weekly traffic patterns. And we also showed how to perform custom online visualizations inside the ThingSpeak web service by using the MATLAB Visualizations App to create a color-coded live traffic indicator that updates continuously as traffic data arrives.

## 5. CONCLUSION

A Raspberry Pi system and USB camera is used to detect, track and count real-time vehicles. The density of vehicles circulating on a particular road is determined in real time. The results of the proposed method with regard to the accuracy and time required are better compared to other methods. Due to the static IP address attributed to the Raspberry system, we can communicate with other remote computers. The performance of the proposed system is superior to 5% to 10% compared to other methods or systems used. It has been found that the cost of the proposed system is much lower than the existing systems. Vehicle detection and tracking by the system are reliable. The proposed method only considered the color characteristics of the vehicle and made it replace existing systems. The number of vehicles present in the video is calculated in real time. The experimental results demonstrated on a preexisting set of data considered at different camera angles, rear view of the vehicles and different camera heights show flexibility and good precision of the proposed method. A vehicle classification method is also being pursued. The classification method will improve the performance of the system detection.

## References

- Arulselvi S., Sundararajan M., *Smart control system in traffic analysis using RTK-GPS standards*, International Journal of Pure and Applied Mathematics, V-116, I-15 Special Issue, PP-349-352, (2017).
- Arulselvi S., Karthik B., Sundararajan M., *A frame work for road network extraction from remotely sensed high resolution images*, International Journal of Pure and Applied Mathematics, V-116, I-15, PP-355-360, (2017).
- Kochláň M., Hodoň M., Čechovič L., Kapitulič L. and Jurečka M., *WSN for traffic monitoring using Raspberry Pi board*, 2014 Federated Conference on Computer Science and Information Systems, Warsaw, pp. 1023-1026, (2014).
- Mallikarjun A., Vishwanath P.B., *A novel approach in real-time vehicle detection and tracking using Raspberry Pi*, Alexandria Engineering Journal, ISSN 1110-0168, <https://doi.org/10.1016/j.aej.2017.06.008>, (2017).
- Raihan K., Kawser J., et al., *Raspberry Pi Image Processing based Economical Automated Toll System*, Global Journal of Researches In Engineering 13.13, (2013).
- Riyazhussain S., Lokesh C.R.S., Vamsikrishna P. and Rohan G., *Raspberry Pi Controlled Traffic Density Monitoring System*, 2016 International Conference on Wireless Communications, Signal Processing and Networking (WiSPNET), Chennai, pp. 1178-1181, (2016).
- Shinde P.A., Mane Y.B., *Advanced vehicle monitoring and tracking system based on Raspberry Pi*, 2015 IEEE 9<sup>th</sup> International Conference on Intelligent Systems and Control (ISCO), Coimbatore, pp. 1-6, (2015).
- Uke J., Ravindra C. Thool., *Moving Vehicle Detection for Measuring Traffic Count Using OpenCV*, Journal of Automation and Control Engineering Vol 1.4, (2013).

## Quality management and Web 2.0 tools embedded in the agile approach for education

Raluca Dovleac<sup>a\*</sup>, Ahmad Sad<sup>a</sup>, Andreea Ionica<sup>a</sup>, Monica Leba<sup>a</sup>

<sup>a</sup>University of Petrosani, Strada Universitatii nr. 20, Petrosani 332006, Romania

---

### Abstract

Throughout time, quality has gained popularity and has been implemented in various occupational fields, leading to debates and discussions about the role of quality and quality management in the education sector. The necessity of ensuring quality is, however, not the only thing that has made an impact on the educational process, it being a cumulative effort of more forces, with ICT (Information and Communication technologies) and web technologies being some of them. Using ICT in education was always a challenge to enhance learning, especially when it comes to using web 2.0 elements that include blogging. The paper explores the following aspects: (1) Combining gamification elements in class blogs, adding extra enhancements to learning which can be reflected in the student's blogs posts and can be measured using Google analytics and (2) Using quality management tools and creativity techniques to ensure quality for each stage of teacher/student blogging cycle. The purpose of the research is to emphasize an original path to ensure quality in education by integrating quality management tools and web 2.0 tools and using highly effective development approaches such as the ones embodied by the Agile approach.

**Keywords:** quality; quality management; Agile; education; gamification.

---

### 1. Introduction

There is a need in general to motivate students more in learning. An example here are Computers Maintenance students labeled as students at risk in a vocational school. They tend to have low motivation for learning and have many problems concerning education like poor attention, high dropout rate, behavior problems. The term student “At-Risk” is used to describe students who are in danger of not meeting educational goals such as graduating from high school or acquiring the skills necessary to become contributing members of society, some of them exhibit disruptive behavior that interferes with their learning. These students' background characteristics may place them at or below the poverty level. Other characteristics include low grades and tests scores, abundant absences from school, and low motivation. At-risk students usually feel that they are overwhelmed by the content covered in regular high school. They may have different learning disabilities that make reading and writing difficult for them.

The required approach should be based on using technology in education because as previous studies show, technology can be used to motivate these students (Madrazo, 2011), (Barley, 2002), research revealing how feelings of autonomy, extrinsic and intrinsic goal orientation, and task value are related to increased motivation among at-risk students (Madrazo, 2011). Information and Communications Technologies (ICT) have been widely perceived as the lever that would lead to significant educational and pedagogical outcomes and support students' development on the knowledge and skills needed to succeed in the 21st century society, where the graduates of secondary school needed to have for the digital literacy requirements (i.e. ICT skills, Critical thinking skills, and ethical skills). So the required model needs to be simple to use, easy to apply and easy to deploy. It shouldn't require powerful PC not available in all areas. It should be free to use and continues to stay free and shouldn't require any installation fees. Web 2.0 applications including blogs, wikis, social networking, social bookmarking, RSS, podcasting, media sharing etc., have enabled students to master many parts of the digital literacy requirements.

---

\* Corresponding author. Tel.: +40 720 109 740

E-mail address: raluca.dovleac@yahoo.com

Academics, researchers, educators and policymakers have advocated that the emerged Web 2.0 applications have the potential to offer enhanced learning opportunities for both students and educators and support lifelong competence development (Jimoyiannis and Angelaina, 2012). Using blogs in the classroom can help increase student learning using student's preferred learning style, personal interest, and engagement. It also encourages self-reflection for the student and critical thinking. Blogs allow collaboration that promotes a constructive environment. And for low-achieving students blogging can give the "silent student" a voice by allowing them the opportunity to write on topics of interest (Sawmiller, 2010). Figure 1 shows a teacher blog with all the assignments for the year 2018 for the Computer Studies class of students.

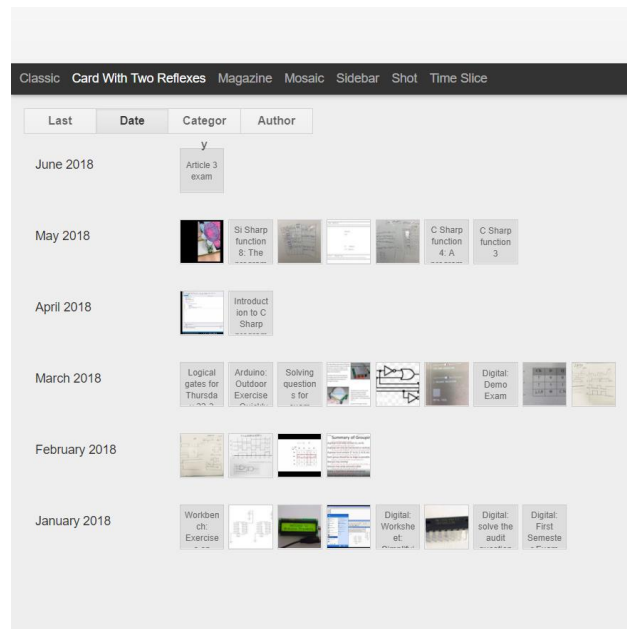


Fig. 1 Teacher blog with assignments divided per months

Figures 2 and 3 show some of the metrics displayed by Google Analytics and available for the teacher's blog to help him understand the behavior of his students and get more insight into what interests them. The teacher can learn valuable information about the students and their behavior such as: what time of the day they are more likely to be working on their assignment, how much time they spend on average on the webpage, what type of device they are logged in from, which pages (assignments) have the most visits and so on.



Fig. 2 Metrics from Google Analytics

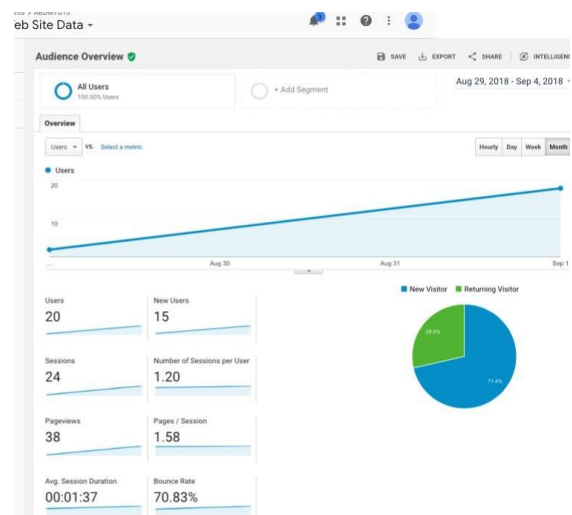


Fig. 3 Audience Overview dashboard

The usage of blogs in the teaching process has been noted also in the case of the Agile Teaching/Learning Methodology (ATLM) which is an approach to the teaching/learning process based on principles of the Agile Manifesto. The application of ATLM has been proven to be successful for increasing student individual study, motivation and results. This approach is based on the Agile software development approach and it advocates that software development is very similar to the teaching process in the sense that it involves multiple parties with different

objectives, limited resources, tight schedules and fixed deadlines and a lot of both expected and unexpected changes. The main focus of this approach is to take the teacher out of the learning loop and give the students the possibility of becoming more autonomous and involved in their learning endeavours (Hon and Chun, 2004).

The similarities between the Agile approach and the Teaching process can be best observed in Figure 4 where on one column the four Agile core values are written while the other column shown the correspondence between these and the teaching process.

Agile core values	Teaching process correspondence
Individuals and interactions over processes and tools	Putting an emphasis on the interaction with the student rather than the medium of interaction.
Working software over comprehensive documentation	Quantifiable results obtained through Google analytics rather than basing decisions on the result of a test paper
Customer collaboration over contract negotiation	Active listening to what the students understand and what they are interested in. Being able to quickly resolve issues and misunderstandings.
Responding to change over following a plan	Adapting the lessons according to the results observed by the teacher in regard to the efforts of his students and the results

Fig. 4 Correspondence between Agile and teaching

The two main concerns that arise from this approach relate to the possibility of integrating gamification tools and techniques in the educational process for the case of Agile ATLM and any other approach focused on blog related teaching activities on one hand, and the means of ensuring quality of the educational process for the case of the Agile ATLM. In the next sections of the paper we look at these problems and provide tools to help solve them.

## 2. Materials and methods

The paper proposes the integration of quality management tools and gamification tools and techniques in order to both help ensure quality within the Agile approach used in the case of the educational process as well as help students become even more engaged and motivated.

An important aspect to be considered given the fact that the Agile approach to teaching is used, is of course the necessity of integrating quality assurance practices and activities in the Agile approach to teaching. As it has been noticed by Bhasin in his paper, the best approach regarding the integration of these practices is within the development team's daily activities while making sure that important aspects such as transparency, team collaboration and flexibility are covered. It has also been debated that Agile methodologies can include quality assurance practices within their activities but they must be shaped according to the Agile principles so that they can adapt to the iterative practices of Agile with the purpose of ensuring quality and stability for each iteration of the development process (Bhasin, 2012).

With this in mind, the authors have identified quality management tools that can help ensure quality and stability for each stage of the teaching process. In order to apply these tools and techniques the authors have chosen to guide themselves through the help of the Agile System Development Life Cycle (SDLC) and have used a simplified version of the SDLC as shown in Figure 5. Based on this approach, the authors will create a model that will incorporate quality management tools and gamification tools for every stage of the development lifecycle.

The proposed model was designed for the case of startups looking to implement the Agile approach in their activity, even if they are not software development based startups and it maintains the base idea behind the Agile SDLC (Dovleac and Ionica, 2017).

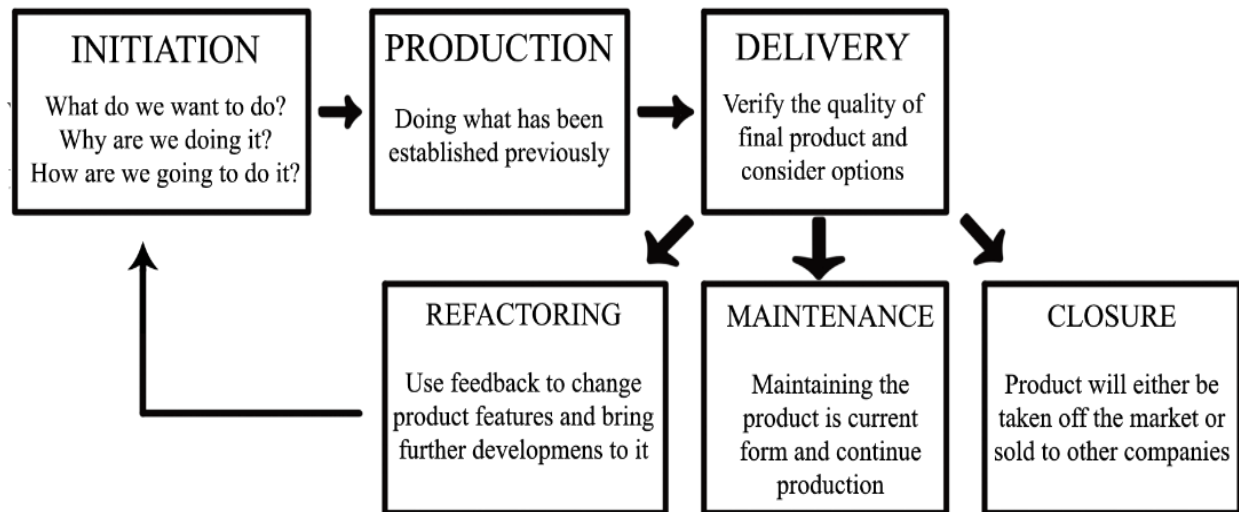


Fig. 5 Simplified Agile SDLC (Dovleac & Ionica, 2017)

The model, applied in the case of the educational process would involve the following activities in each of its development phases:

- **Initiation phase:** During this phase the teacher studies the curriculum and, if possible, gathers info about the students and their environment. He then divides the lessons into small chunks of information that are easy to understand and intractable enough to capture the attention of the students. At this stage, the teacher can also develop exercises with different degrees of difficulty for the first lessons in order to make sure that everybody is engaged. Furthermore, the integration of gamification tools can begin with this stage, where the teacher can plan how the students will remain engaged and rewarded through the help of gamification tools such as: achievement points and badges. Still in this stage, the teacher creates a class blog and furthermore guides the students into creating their own blogs and gmail accounts if necessary. Furthermore, in this stage, the teacher makes sure that the whole class understands the way the lessons will be taught and is familiarized with the Agile principles.
- **Production phase:** During this phase the teacher releases new assignments and lessons every week while gathering feedback from students. In this phase, the students complete their assignments, ask questions and require clarifications.
- **Delivery phase:** This phase takes place after each delivered assignment has been completed by the students and feedback from both Google analytics as well as students has been gathered. In this stage the teacher must decide the impact that the lesson had on the students and take actions accordingly. The available actions are:
  - **Closure:** the students failed to understand the lesson and upon closer examination the teacher can see that the lessons might not have been appropriate for the level of knowledge of the students or was not interactive enough, explanatory enough. The lesson is left behind as it is and the teacher focuses on delivering the same lesson differently.
  - **Maintenance:** the teacher evaluates the results as being according to the established goals and furthermore the students agree, therefore the template for the next lesson will remain similar.
  - **Refactoring:** the students understood the lesson but they had major difficulties and so the future lessons must be improved, refactored.

Given the fact that the Agile approach is focused on delivering iteratively small chunks of product rather than the whole product at once, the cycle will repeat in the sense that after the teacher completes one of the three alternatives following the Delivery phase, he must return to the Initiation phase in order to design and deliver the next lesson/assignment to the students.

The integration of quality management tools for each stage of the development process in the case of the Agile teaching approach proves to be therefore useful in order to guarantee that quality assurance best practices are met. Figure 6 shows how quality management tools can be integrated for each stage of the process, while Figure 7 shows how gamification tools and techniques can be implemented in order to obtain the best results.



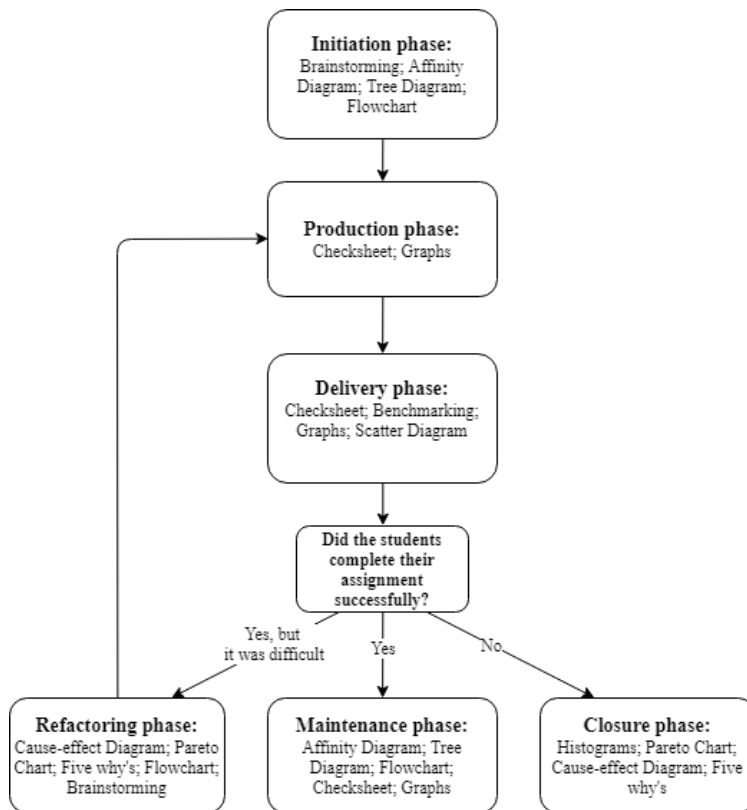


Fig. 6 Quality management tools integrated in Agile teaching approach

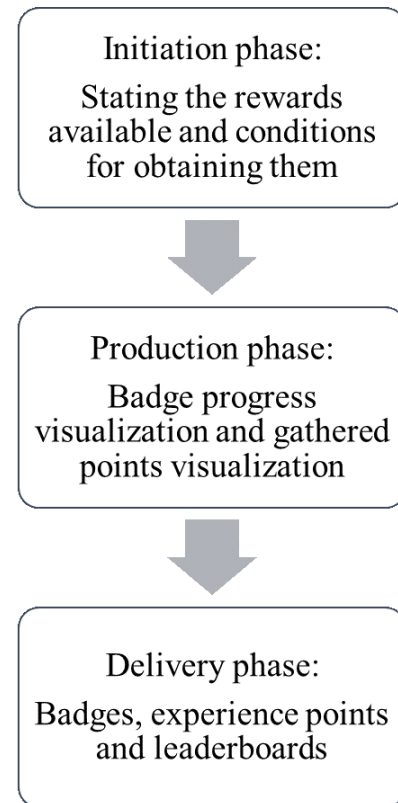


Fig. 7 Gamifications tools used in Agile teaching approach

As it can be seen from Figure 6, some of the quality management tools used in one stage of the development process may be used later for other stages if necessary. Furthermore, in the paper the authors considered just the most quality management tools but the implementation of other, newer quality management tools is possible. Figure 7 shows some of the most basic gamification tools and techniques that can be used in the main phases of the development process in the case of applying Agile approach principles to the teaching process in order to both help ensure the quality of the educational act as well as help improve the motivation for study among students.

### 3. Results

Information and Communications Technologies (ICT) have been widely perceived as the lever that would lead to significant educational and pedagogical outcomes and support students' development on the knowledge and skills needed to succeed in the 21st century society, where the graduates of secondary school needed to have for the digital literacy requirements (i.e. ICT skills, Critical thinking skills, and ethical skills).

Web 2.0 applications including blogs, wikis, social networking, social bookmarking, RSS, podcasting, media sharing etc., have enabled students to master many parts of the digital literacy requirements. Academics, researchers, educators and policymakers have advocated that the emerged Web 2.0 applications have the potential to offer enhanced learning opportunities for both students and educators and support lifelong competence development (Jimoyiannis and Angelaina, 2012).

Based on the blog implementation in the educational process, approaches meant to help improve it have emerged such as that of Hon and Chun, who both proposed and demonstrated the utility of implementing an Agile approach to the teaching and learning process (Hon and Chun, 2004).

The original contribution of the authors of the paper regarding this subject is the implementation of quality management tools to help ensure quality of the educational process for the case of teachers using the Agile development style as well as including gamification tools and techniques to help raise student interest and motivation. The proposed model can be further improved by integrating more or newer quality management and gamification tools.



## References

- Barley, Z., Lauer, P. A., Arens, S. A., Apthorp, H. S., Englert, K. S., Snow, D., & Akiba, M. Helping at-risk students meet standards: A synthesis of evidence-based classroom practices. Aurora, CO: *Mid-continent Research for Education and Learning* (2012).
- Bhasin, S. Quality Assurance in Agile: A Study towards Achieving Excellence. *Proceedings - Agile India 2012*, 64-67 (2012).
- Dovleac, R., Ionica, A. Quality Management techniques embedded in Agile Project Development. *MSE*, 121 (2017).
- Hon, A., Chun, W. The Agile Teaching/Learning Methodology and Its e-Learning Platform. *Advances in Web-Based Learning – ICWL*, 11–18. Beijing: Springer (2004).
- Jimoyiannis, A., Angelaina, S. *Towards an analysis framework for investigating students' engagement and learning in educational blogs*. *Journal of Computer Assisted Learning* (28)3, 222–234 (2012).
- Madrazo, D. *The Effect of Technology Infusion on At-Risk High School students Motivation to Learn. A PHD Dissertation in Education*. Doctoral Program in Educational Leadership Reich College of Education (2011).
- Sawmiller, A. *Classroom Blogging: What Is the Role in Science Learning?* *Clearing House: A Journal of Educational Strategies, Issues and Ideas* (83)2, 44-48 (2010).

# Quality in Web Design – Trends and responsiveness techniques

Luminița Giurgiu<sup>a\*</sup>, Dănuț Moșteanu<sup>a</sup>

<sup>a</sup>“Nicolae Bălcescu” Land Forces Academy, Revoluției Street no.3-5, Sibiu, Romania

---

## Abstract

Offering the same support to a variety of devices for a single website became an unquestionable common issue of quality in the web design area. The ability of a website to adjust and fit to different devices and resolutions on which is displayed without undergoing degradation is nowadays a matter of both interest and normality.

Because a responsive website can provide an optimal viewing experience - without resizing, zooming or scrolling across most devices, web designers have addressed this challenge with many and different solutions. To keep up with the changes in web design, this article intends to discuss some trends, techniques and solutions with specific references to the Land Forces Academy site.

*Keywords:* responsive techniques, web design trends.

---

## 1. Introduction

Generally speaking, trends in web design can have several roles: from a more appealing and more functional webpage to traffic and subsequent conversions. Why does a website need to keep up-to-date appearance and functionality? Considering the evolution of technology, many websites have experienced a few frequent changes so visitors can enjoy pleasant experiences no matter how they access them.

The concept of responsive web design is not something new; it has existed for a few years, more precisely since the transition to CSS3 and HTML5. A responsive web site responds correctly and displays the items on the page as best as possible, depending on the resolution of the detected screen. We cannot talk about a separate version of the site, compatible with mobile devices, but we have only one version that is displayed correctly regardless of the device. It must display information and graphic theme correctly regardless of the browser used, screen resolution, or operating system.

## 2. Some trends in short

The main focus for any company, institution or private person is, or at least should be, the customer experience, while aesthetics and functionality remain basic principles. Because most of the traffic comes from the mobile area - for the 2018 web design - the adaptation to the mobile phone remains a priority. The following trends, each of them is user-centered and based on the relation between experience and website.

### 2.1. Responsive design

Web responsive design - as it has become a necessity, it is a little exaggerated to call it a trend in 2018, but still in this category. Flexibility of design is therefore a requirement of the market before it is an advantage over competitors. More than that, a good result on search engine results pages will be obtained if the site benefits from a responsive web design because search engines will index the pages much easier and recommend it to users.

---

\* Corresponding author. Tel.: 0744387557  
E-mail address: luminita.giurgiu.a@gmail.com

## *2.2. Flat design interface*

The flat design interface - remains a trend this year. That means minimalism, full colors, simple elements and a design that let information be the first. Beyond that, it is important that the mobile version can perform through its relevance, simplicity and airy spaces. So nothing new about this trend, but it is already known that flat web design websites are easy to access and use, they have friendly and colorful interfaces. In fact, the simplicity of this design concept and the lack of loading pages with all sorts of unnecessary elements are very much appreciated. This design airflow helps users to navigate content more easily without distracting them. So, the content is leading.

## *2.3. Images at high resolutions*

Using images at high resolutions - because of a narrowband bandwidth, the images were loaded at low resolutions not long ago. However, with the improvement of Internet connections and the increase of Internet speed, this constraint is no longer valid.

That is why the sharp and large images that, because of the new techniques, can be used as wallpaper, being resized and optimized so as to considerably reduce the loading time of the page, is preferred. Large images, especially those used as a backdrop of a website, have a double utility: on the one hand, they make the site more attractive and simplified and, on the other hand, manage to communicate the message clearly and effectively size.

## *2.4. Scrolling*

The scroll option - regardless of the new techniques that web designers adopt, the scroll option is and will continue to be one of the most used, as it is closely related to the responsive design. This is highly sought after and appreciated by mobile device users. Scrolling considerably reduces the additional time it takes to load a page and simplifies browsing of users by giving them fluency.

## *2.5. Irregular grid layout*

Irregular grid layout – using the CSS grid technique that allows web developers to create complex responsive web design layouts more easily and consistently across browsers, any content in the same width and thickness can be resized, displaying it in columns of any height.

Among the advantages is the fact that it is attractive to the eye regardless of the loading elements: news, event pages, press releases, photo galleries.

## *2.6. Artificial intelligence*

Artificial intelligence and reinvent the homepage - artificial intelligence is already part of the website structure in the form of personalization of messages by user or computer chat support. It is expected to be present more and more on sites and will revolutionize the way we communicate. It is also closed related to the reinvent of the homepage. In 2018 it is expected that the structure of the homepage will have the most changes. New websites, as well as already consolidated brands with great openness to innovation, move further away from the traditional homepage, meaning that one of the company's priorities will be to create a personalized experience for each individual user depending on the location, history, or data they know about him. Thus, the content he sees and interacts with will change according to the specificity of each user.

## *2.7. Sticky menu*

Sticky menu - it is located in a fixed space on the page where it does not disappear, even browsing the page, so it is accessible to all users without having to scroll. Web site designers have begun to introduce this kind of fixed menus at the bottom of the site that allow to go back without having to navigate back to the top. Modern functionality is a need that remains mandatory and the bottom of the screen seems to be more functional in 2018.

## **3. Responsive design**

As a concept, responsive design, it is based on three fundamental elements: media queries, flexible images that change their size and fluid grids that take screen resolution into account.

### 3.1. Media Queries (@media)

Introduced in CSS3, Media Query is a CSS technique providing an effective way to load different CSS styles for different resolutions. By imposing CSS style conditions depending on screen resolution, @media includes a CSS property block only if a certain condition is true (Frain, 2013). Let's see an example where the browser window is less than 600px, the background color will change to blue and the edge of the menu's div will be eliminated:

```
@media only screen and (max-width: 600px) {
  body {background-color: blue;}
  .menu {margin:0px;} }
```

By the use of a series of similar queries, different conditions could be created for different resolutions: 320px, 480px, 600px, 768px, 900px, 1200px. More than that, any number of conditions can be used, if necessary.

### 3.2. Flexible, fluid images

Another key element is the flexible image. Flexible, fluid images particularity consists in changing their width and height according to the resolution and size of the grid. For this purpose, images are saved on the server in a certain number of dimensional sets, of which the corresponding image will be loaded, depending on the size of the screen. Among the techniques used to resize images proportionally, the most popular is the maximum width:

```
img {max-width: 100%; height: auto}
```

This way, the maximum image width will be 100% and if it decreases, the same will happen with the image. So, flexible or fluid images cause the adjustment of the size to the parent block. The consequence is that if the parent block is smaller than the image size, then the image is reduced proportionally. The same technique applies for the flexible embedded videos.

### 3.3. Fluid grids

The use of fluid grids is a very important step in responsive web design. Considering the large number of resolutions today, the fluid grids' benefits cannot be ignored. Fluid grids are based on percentage sizes, being very well calculated. The layout's elements are all scaled to each other and the measurements are not made in pixel dimensions, but in percentages and relative units. Thus, when the website is scaled to a very low resolution, all its elements shrink and perfectly align with each other. In order to obtain such a result, the best way is to realize a high resolution design, to take each item measures and to do the division of the element width by the design width.

## 4. Some responsiveness techniques used in the Land Forces Academy official web site

The responsive version of the academy official website has considered the three elements described above, and involved the use of several techniques, of which only three would be discussed:

### 4.1. The breakpoints setting

Breakpoints have to be set in places where it is needed so that the page elements move suitably to display well on screen. For setting the breakpoints where the content starts to look bad as the screen shrinks, the dimensions of the page's elements need to be measured in pixels. Using Google Chrome, activating "Inspect element" mode, and then tracing the edge of the appeared section until the page starts not looking well could be the way of establishing these dimensions. Next, breakpoints are set using Media Queries in CSS (Marcotte, 2015). So, a breakpoint could be added where certain parts of the design will behave differently on each side of the breakpoint. For example, a media query was used to add a breakpoint at 768px; when the screen gets smaller than 768px, each column should have a width of 100%.

The example in figure 1 shows that the difference between the classes is only the name and it gives the possibility to determine how the breakpoints affect the columns:

- Case of extra small devices Phones (<768px) it would be considered the class prefix col-xs-\*. Because the place is very limited the arrangement of the elements must be well thought-out so clarity is preserved. In most cases, the menu from the navigation area will become an icon. The menu adapts itself to the small space by line breaks and the selection boxes for the target group selection disappear. The options of the selection boxes are moved to a different level and sublevel in the menu.

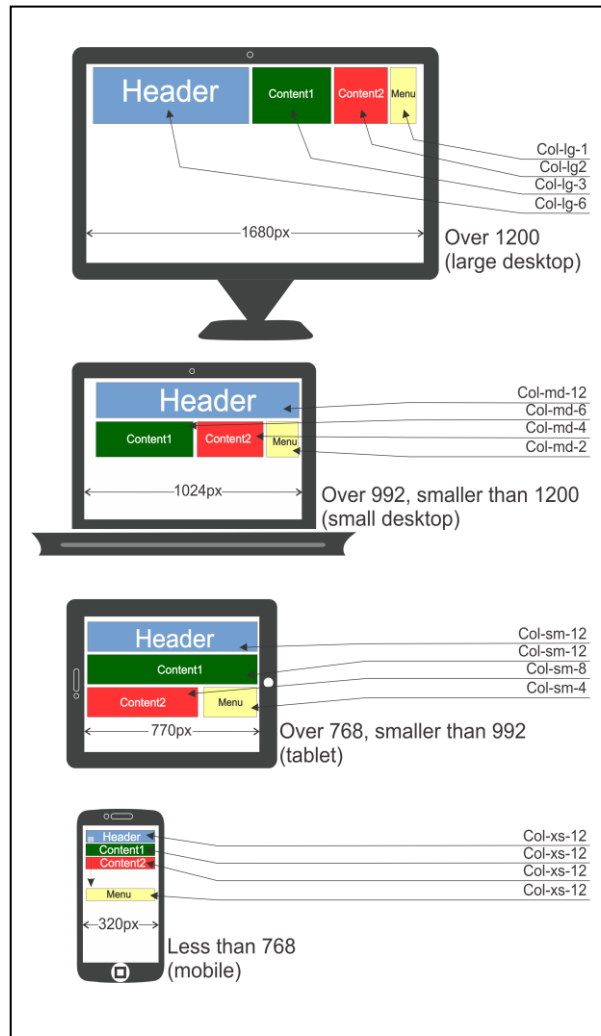


Fig. 1. Responsive design technique – setting the breakpoints

- Case of small devices Tablets ( $\geq 768\text{px}$ ) it would be considered the class prefix `col-sm-*`.
  - Case of medium devices Desktops ( $\geq 992\text{px}$  and  $< 1200\text{px}$ ) – it would be considered the class prefix `col-md-*`.
  - Case of large devices Desktops ( $\geq 1200\text{px}$ ) - it would be considered the class prefix `col-lg-*`.
- The symbol “\*” signifies a number: `.col-md-3` creates a column three times the size of a `.col-md-1` column; `.col-xs-10` creates a column ten times the size of `.col-xs-1`, etc.

#### 4.2. Graceful degradation and progressive enhancement

Given the existing content, the new construction of the website had to consider the two approaches represented in Figure 2:

- First - if the website already exists, it is possible just a redesign. It is called *graceful degradation*, where the detailed site for large screen has to gradually stretch down. The smaller the screen, the more elements of the page need to be omitted, condensed or remapped to keep the site clear and easy to use.
- Second - for a fresh new start, the concept is mobile first and it is called *progressive enhancement*. It means that first is created a page for the smallest screen and finally for the large screen, because the better a page is essentialised to the substance, the more evident and useful it is on small end devices. Then, the mobile-focused view of the site is progressively enhanced to the more refined tablet view and finally to the large desktop version with all the images, details, animations and information that appear on the smaller display also.

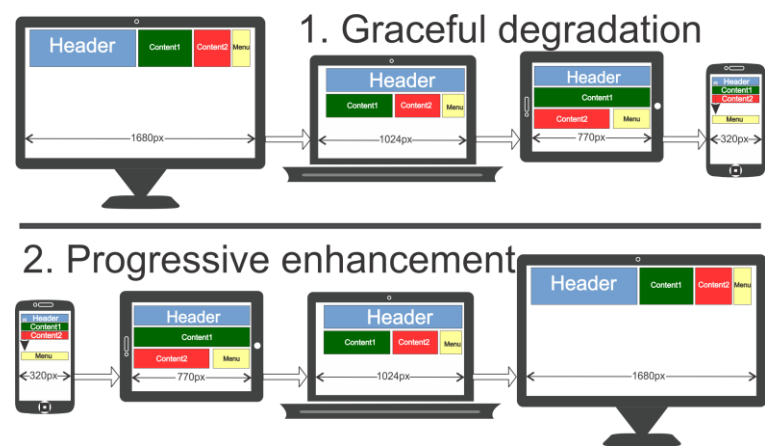


Fig.2. Approaches in the redesign of the site

The effort was done in the second direction and the official website of the academy respects the same approach in both English and Romanian versions. By actually working on the redesign of the site, I came to the conclusion, which was originally planned from the beginning that the natural, real trend in web design is to create the site starting from the screen of mobile devices and not from the desktop screens.

The justification of the importance of the presentation level is given by getting in user interaction. The presentation level is what the end user sees after all the app processing, so it must be up to the required complexity. Being simple and intuitive, no matter how elaborated its structure is and how complicate the system, the website fulfills the user's desire to navigate quickly, clear and agreeable.

4.3. Responsive layout and responsive classes

Responsive layout refers to the use of columns. By default, Bootstrap uses the 12-column system. A graphic representation is shown in figure 3. The calculation of column sizes was done using formula  $12/x$ , where  $x$  is the desired number of columns.

.col-md-1	.col-md-1	.col-md-1	.col-md-1	.col-md-1	.col-md-1	.col-md-1	.col-md-1	.col-md-1	.col-md-1	.col-md-1	.col-md-1
.col-md-8								.col-md-4			
.col-md-4				.col-md-4				.col-md-4			
.col-md-6						.col-md-6					

Fig.3. Bootstrap 12 columns system

For a response to different devices, bootstrap classes were also used in the site code. With the help of the responsive utility classes, the content is hidden or displayed, depending on the device. Figure 4 shows a table of correspondence between the available classes and their effect on a given media query aspect.

	Extra small devices Phones (<768px)	Small devices Tablets (≥768px)	Medium devices Desktops (≥992px)	Large devices Desktops (≥1200px)
.visible-xs*	Visible	Hidden	Hidden	Hidden
.visible-sm*	Hidden	Visible	Hidden	Hidden
.visible-md*	Hidden	Hidden	Visible	Hidden
.visible-lg*	Hidden	Hidden	Hidden	Visible
.hidden-xs	Hidden	Visible	Visible	Visible
.hidden-sm	Visible	Hidden	Visible	Visible
.hidden-md	Visible	Visible	Hidden	Visible
.hidden-lg	Visible	Visible	Visible	Hidden

Fig.4. Responsive utility classes

## **References**

- Frain, B., *Responsive Web Design with HTML5 and CSS3*, Packt Publishing, (2013).  
Marcotte, E., *Responsive Web Design, Second Edition*, Publisher: A Book Apart, (2015)  
<https://idea-perpetua.ro/10-tendinte-in-webdesign-pentru-2018/>  
<https://www.conceptwebdesign.ro/>  
<http://howtocodeinhtml.com/HowToCodeInHTML5AndCSS3.pdf>  
<https://designingfortheweb.co.uk/>  
<https://www.armyacademy.ro/>  
<http://getbootstrap.com/css/>



# Exoskeleton for improving quality of life for low mobility persons

Marius Risteiu<sup>a\*</sup>, Monica Leba<sup>a</sup>, Andrei Arad<sup>a</sup>

<sup>a</sup>University of Petrosani, Str.Universitatii, no.20, 332006, Petrosani, Romania

---

## Abstract

Exoskeletons were originally created for military applications to help soldiers lift or carry extra weight. From that point the scope has been moved to other applications, among others to help the people who have suffered a stroke and therefore have reduced mobility. This paper proposes a model of an exoskeleton to help move the upper limbs of a patient, the control of the exoskeleton being achieved based on signals acquired from EMG sensors.

*Keywords:* EMG; modeling; simulation; robot.

---

## 1. Introduction

The development of the exoskeleton robot technology has started just like many others in the military field. First application of the exoskeleton robot was to give more power to a soldier so he could carry extra weight. Since then, this technology has focused on developing systems for assisting and improving human power. Later, this technology has been used in other applications, such as limb rehabilitation and tele-operations. The research in exoskeleton domain is still a growing area and requires multidisciplinary approaches for solving complex technical problems (Gopura et al. 2015).

This kind of devices were designed with varying degrees of mobility depending on the area which they are rehabilitating. The vast majority of these types of devices are made for upper limb rehabilitation, but there are designs made for the lower limbs as well. The ARMin device, for example, is based on a haptic unit with two-degrees of freedom and the mechanical part is constructed to allow the upper limbs to be rehabilitated in two ways. ARM mode makes flat movements on shoulder and elbow, and WRIST mode performs tasks that move the forearm and wrist.

Hand with the problem is attached to the guide bar that is positioned depending on which mode the device is set to work. Starting from this model, another device named ARMin III has been developed, that is equipped with 6 engines, making the shoulder movements with 3 degrees of freedom, elbow joint, a supination of the arm, and a flexion/extension for the wrist. One of the advantages for this device is the symmetrical construction that can be used for both arms, and control algorithms allow not only device control but also interaction forces between user and exoskeleton (Nef et al. 2009).

Another exoskeleton device is SUEFUL 7 which is capable of assisting in horizontal and vertical movements, shoulder flexion / extension, internal / external shoulder rotation, flexion / elbow extension, forearm supination / pronation, flexion / extension wrist, radial / ulnar deviation of the palpation wrist. SUEFUL 7 has been designed to be worn on the upper limb but since many patients use the wheelchair it has been adapted to fit the seat so that the user is not affected by its weight (Gopura et al. 2009).

In the literature, there are several exoskeleton robots among we mention MIT-MANUS, GENTLE/S, Pneu-WREX and NEREBOT are specifically designed to help arm stretching exercises but lack the ability to assist in wrist and forearm movements. On the other side CRAMER, RICE WRIST, HAND MENTOR and HVAR are robotic devices specially designed to perform exercises for the movement of the forearm and wrist but do not allow the arm to exert other movements. In this field of exoskeleton robots, devices can still be developed because in many cases the devices need to be customized according to the needs of the user because we cannot talk about a standard model in case of people who have difficulty in moving their arms (Kiguchi et al. 2009).

---

\* Corresponding author. Tel.: 0720230078;  
E-mail address: risteiumariusnicolae@yahoo.com

## 2. Exoskeleton design

In this paper we have proposed, model and test a device for improving the quality of life for persons with reduced mobility of upper limbs as shown in figure 1.

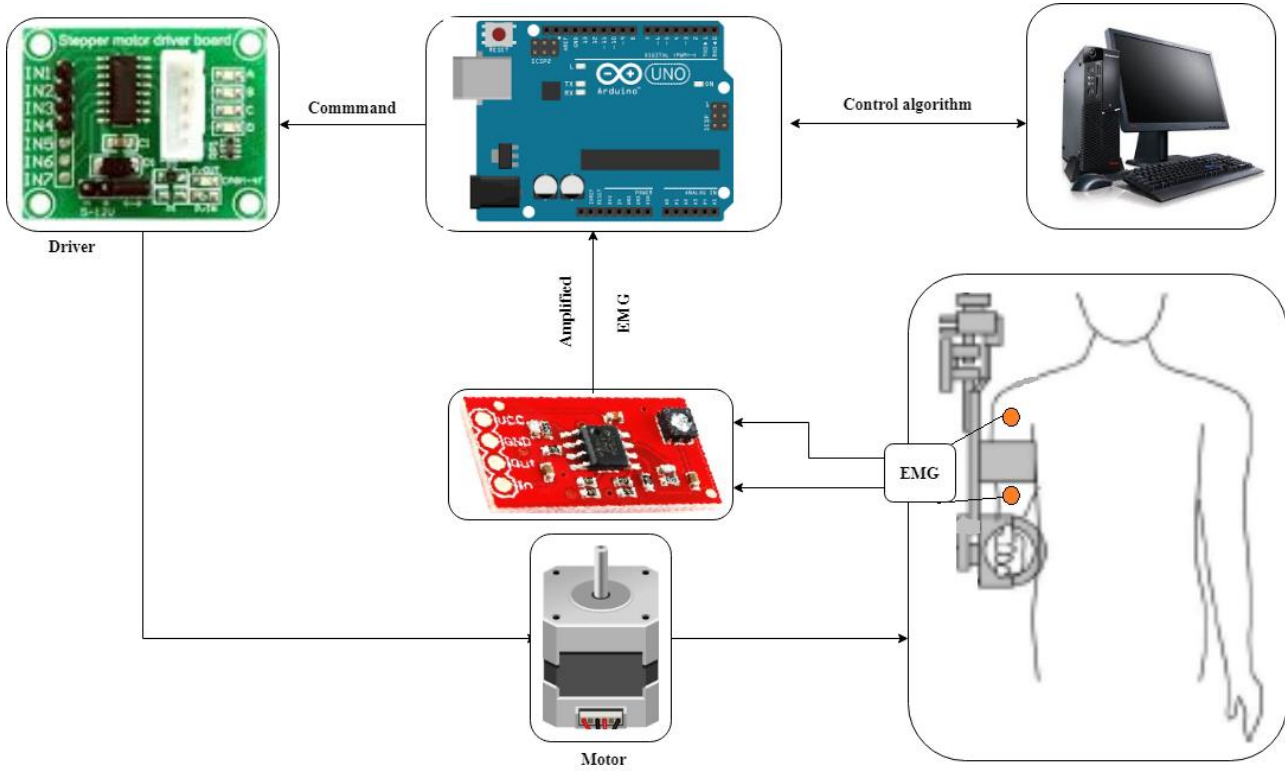


Fig. 1. Block diagram of exoskeleton device

Figure 1 shows the block diagram together with the operating algorithm of the exoskeleton. First, the exoskeleton must be fixed on the right arm of the user and EMG sensor electrodes must be positioned on the muscle groups so that a better signal can be taken. As seen in the above figure after the signal is taken over by the electrodes it passes through the amplifier so the signal to be filtered and amplified. After filtering and amplification, the signal goes further into the Arduino UNO interface board that communicates further with the computer to can use the kinematic models. Once a motion decision is established, the control signal is transmitted to the motor driver by forwarding the signal to the execution element. For the realization of this device it was necessary in the first phase to make a mathematical model of the human arm and a mathematical model for exoskeleton (Kiguchi et al. 2004). After determining the direct kinematical model of the arm, the inverse kinematic model of the exoskeleton was determined to perform the movements according to the user's intentions of movement. Through the kinematic inverse model, we determine the movements each joint must achieve in order to reach the imposed position, meaning the linear translation  $d_1$  and the rotation angles  $\theta_2, \theta_3$ . The matrix of the direct model is:

$$T_{0,3} = \begin{bmatrix} -s_{2+3} & -c_{2+3} & 0 & -d_4 \cdot s_{2+3} - d_3 \cdot s_2 \\ c_{2+3} & -s_{2+3} & 0 & d_4 \cdot c_{2+3} + d_3 \cdot c_2 + d_2 \\ 0 & 0 & 1 & -d_1 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Based on the Denavit-Hartenberg direct kinematic model previously developed, there was designed the simulation model in MatLab-Simulink-SimMechanics, as presented in figure 2.

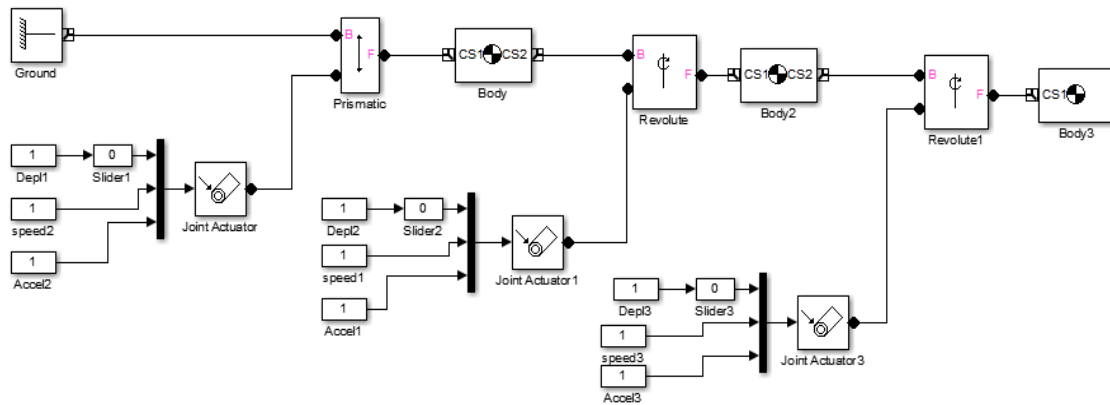


Fig. 2. Matlab Simulink SimMechanics exoskeleton model

There was implemented the direct model, as can be seen from the sliders in figure 3 representing each joint actuation, first joint in a prismatic joint and the other two are revolute joints.

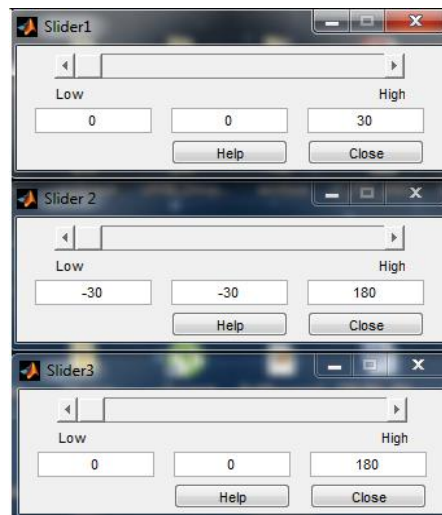


Fig. 3 Direct model

In figure 4 is presented a position of the exoskeleton that corresponds to the position presented in the sliders from the same figure.

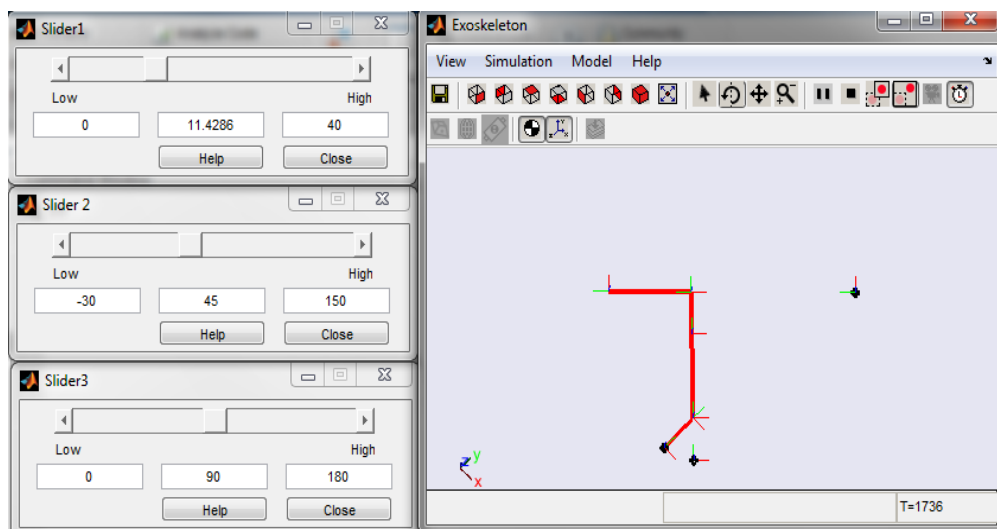


Fig. 4. Simulation results

### 3. EMG based controller

The electromyography (EMG) sensors take the value of electrical voltage that occurs at the level of the muscular endings. Electrodes used for EMG sensors can be two types:

- invasive – are intramuscular electrodes, with a needle inserted into the muscles to retrieve the signal
- noninvasive – are surface electrodes that have a conductive gel placed over them and stick to the surface of the skin (Norali et al. 2009).

Due to the fact that the non-invasive ones are easier to use without causing any discomfort to the person monitored in this project we have chosen to use them. With the help of the signals received from non-invasive EMG sensors, the left/right control circuit of a servomotor was designed as shown in figure 5. This represents a testing prototype for the control system of the exoskeleton.

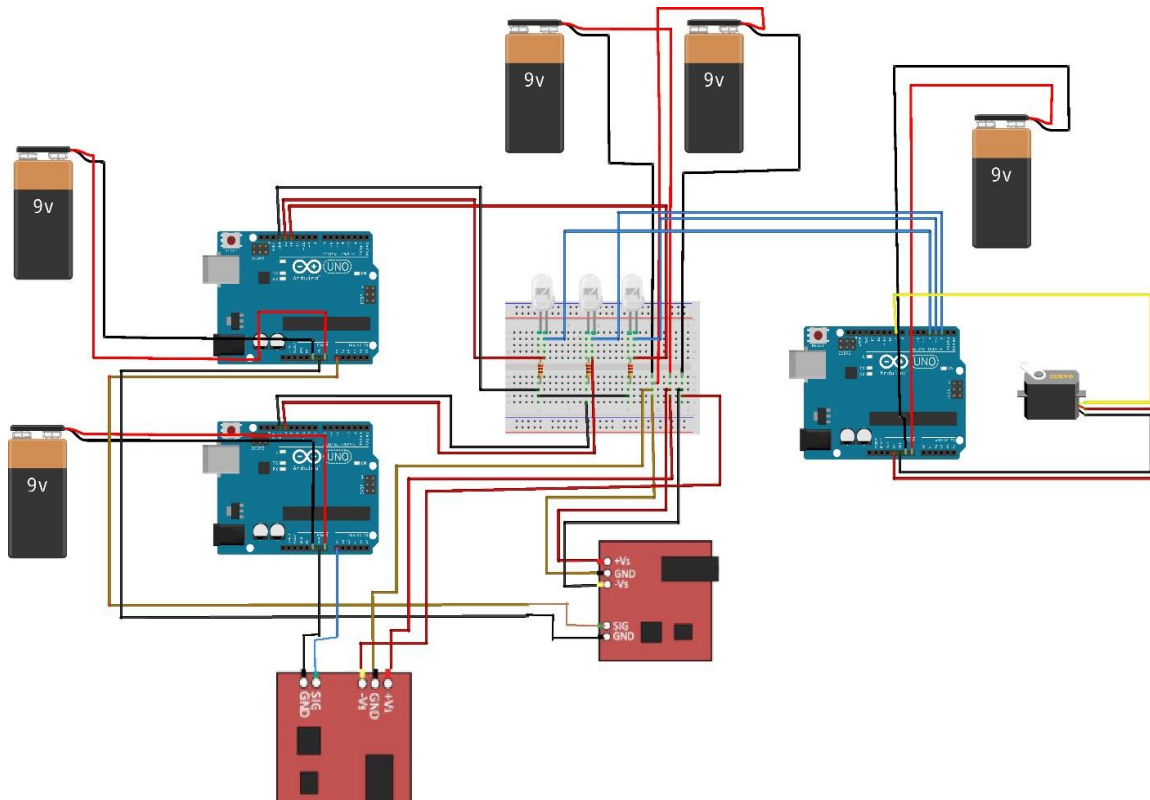


Fig. 5. EMG based control diagram

Three Arduino UNO development boards and two MioWare V3 EMG sensors were used to implement this assembly. The two EMG sensors are connected to 2 Arduino boards that deal with data acquisition. The two boards are designed to monitor the signals received from the sensors, but also to interpret these signals according to the muscles that are observed. Depending on the signal amplitude, the microcontroller interprets what we call the intention of flexion or extension of the muscle.

At first, the implementation of the system was attempted on a single Arduino board but due to the fact that sensor readings take a sufficient period of time to be able to affect the operation of the engine and that there were interferences between the sensors reads on the same development board so we decided to implement these components on 3 different boards.

The two data acquisition boards are programmed to emit a digital signal depending on the intent of the monitored muscles. The third board is used to interpret these digital signals. Depending on the intentions of the muscles, it will make the decision to move the servomotor.

The system presented can be used to simultaneously monitor 2 muscles, and to make decisions based on these intentions.

At the time of implementation, the muscles we considered were biceps and triceps. The studied movement as well as the one for which the system was implemented is the flexion or extension of the elbow. Depending on how the person who wears the sensors moving the elbow the device moves also, it is possible to determine with these sensors the intention as well as the direction of movement.

In fact, the whole system is based on these two variables that take values according to the signals received from the muscles. There must be an intention to move the arm in a certain direction in order to achieve a valid interpretation.

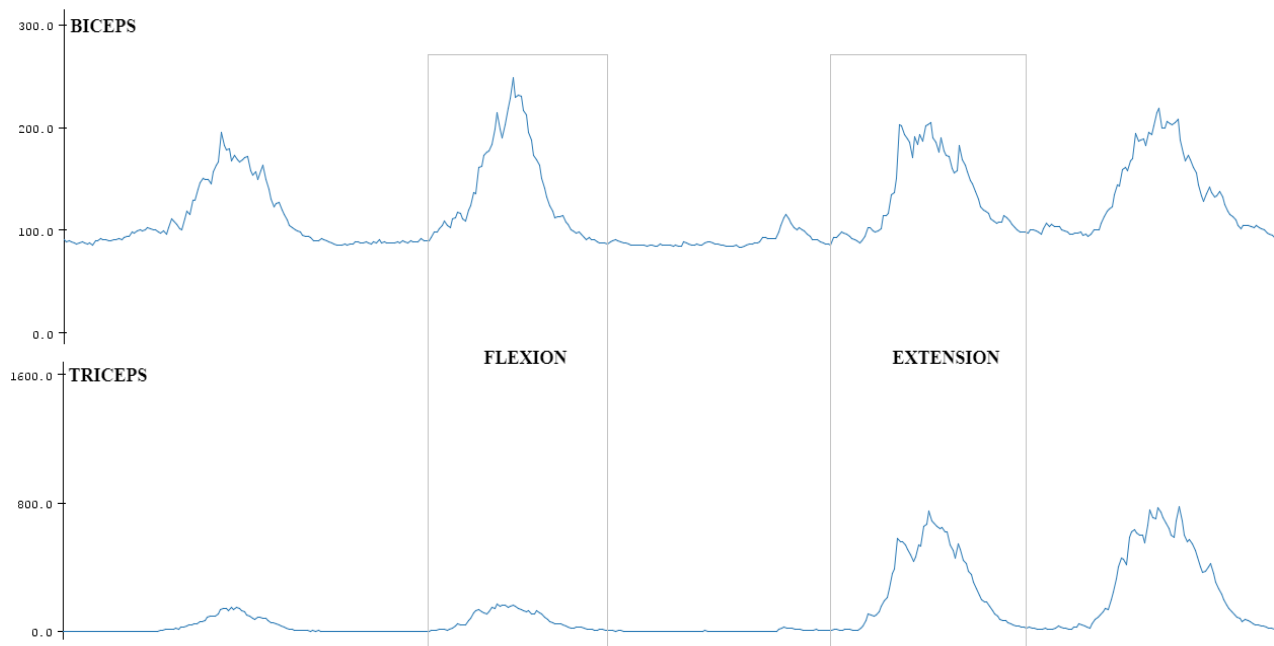


Fig. 6. Signals from EMG sensors and identified movement

Figure 6 shows the signals taken from the biceps and triceps during the flexion or extension elbow movement. Depending on the signal amplitude, the two boards responsible with the data acquisition decide whether there is a motion intention and the direction in which the motion is desired. Forced arm strain without moving it in a certain direction will only produce a motion signal, not a specific direction.

The program written on the acquisition boards microcontroller checks whether the analogue value exceeds the minimum value from which the signal may be interpreted. If this condition is met, the program performs a series of 50 readings that must be greater than the minimum declared value in order to consider the signal as a moving intent. If second condition is also met, the program changes the state of a digital pin to indicate that it has detected a motion intention. This algorithm is implemented on both Arduino boards, the difference being that the board on which the direction is implemented has two constant values defined, and depending on these two values, it decides the direction of motion. If the signal is too weak, it is ignored because it may represent noise from imperfect contact between electrodes and skin or there exist an electromagnetic field.

Also, in order to avoid delays in the coupling movement, the program also has a condition that once the engine starts to move, it is necessary to eliminate the intention to move equivalent to another 50 readings to stop the engine. Of course, due to the short time between readings, it can be approximated that 50 readings are performed in approximately 500ms. The condition that dictates that the engine will only stop after 50 readings from the disappearance of the intent has been implemented because erroneous readings can occur that are far below reality and without this condition would stop the engine for other 500ms.

These constants that were previously spoken as the minimum values over which the signal is considered are threshold values, and are obtained by studying a user's muscular activity and are valid only if the device is used by that user.

Also due to imperfect contact between sensor electrodes and skin and various types of electrodes, these values are only valid for one use. Removing electrodes and sticking to others even if this is done in exactly the same place can have major influences on how the electrode reads muscle tensions, and as a result they will lead to interpretation mistakes.

The disadvantage of using non-invasive electrodes is that they are imprecise because they depend on how they are bonded to the skin as well as on the level of contamination of the contact gel. From this point of view, invasive electrodes, even if they cause major discomfort in practice, are much more useful and the data taken from this type of sensors can often be repeated easily if the electrodes are placed in the same places.

#### 4. Conclusions

Exoskeleton robots are a combination of human intelligence and the machine power. Due to the fact that the world population is in an ever-aging and more and more people get limb movement deficiencies, exoskeletons are needed in rehabilitation operations and for improving the quality of life.

Exoskeletons based on an electromyographic controller are, from our point of view, some of the easiest to implement as long as there is muscle activity. Where very high precision is not required, it is much easier to use non-invasive electrodes because the invasive ones need a more sterile environment and can cause infections if inappropriately used.

The proposed exoskeleton, modeled and tested in this paper, is based on an EMG controller with non-invasive electrodes and was designed to assist the movement of the upper limb of a person with partial motion disability.

## **References**

- Gopura RARC, Bandara DSV, Kiguchi K, Mann GKI. Developments in hardware systems of active upper-limb exoskeleton robots: A review. *Robot Auton Syst.*, (2015).
- Nef T, Guidali M, Klamroth-Marganska V, Riener R: ARMin - Exoskeleton Robot for Stroke Rehabilitation. *In World Congress on Medical Physics and Biomedical Engineering*, (2009).
- Gopura RARC, Kiguchi K, Li Y: SUEFUL-7: A 7DOF upper-limb exoskeleton robot with muscle-model-oriented EMG-based control. *In IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*. St. Louis, MO;1126-1131, (2009).
- Kiguchi K., Tanaka T., Fukuda T., "Neuro-fuzzy control of a robotic exoskeleton with EMG signals", *IEEE Trans. Fuzzy Syst.*, vol. 12, no. 4, pp. 481-490, (2004).
- Kiguchi K, Rahman MH, Sasaki M, Teramoto K: Development of a 3DOF mobile exoskeleton robot for human upper-limb motion assist. *Robotics and Autonomous Systems*, (2008).
- Norali, A., Som, M. M. & Kangar-arau, J. Surface electromyography signal processing and application: A review. *In Proceedings of the International Conference on Man-Machine Systems*, 11–13, (2009).

# Increase the quality of temperature measurements using virtual instrumentation

Nicolae Patrascoiu<sup>a\*</sup> Cosmin Rus<sup>a</sup>

<sup>a</sup>University of Petrosani, Str.Universitatii, no.20, 332006, Petrosani, Romania

---

## Abstract

For temperature monitoring, there are many options that are determined either by the type of sensor used or the method of acquisition and processing data from it. In this paper, we propose such a temperature monitoring system by using semiconductor integrated sensors and an open source platform based acquisition module. The proposed system allows the selection of available several sensor static characteristics used and their treatment by means of interpolation methods to process the data thus obtained.

*Keywords:* integrated sensor; LM 9402x; Arduino Uno; spline interpolation; LabView.

---

## 1. Introduction

Obtaining temperature information allows either adjusting it in a process or system, or collecting data about other physical variables whose values can be temperature dependent. As is known in the temperature measurement, different types of sensors are used according to the functional principle. Thus, resistance temperature detectors (RTD), thermistor, thermocouple, or p-n junction can be used.

It is known that the temperature sensitivity of the p-n junction is part of the transistor's defining equations and is quite predictable over the typical semiconductor operating range of  $-55^{\circ}\text{C}$  to  $+150^{\circ}\text{C}$ . Starting from this observation, the semiconductor temperature sensors are made and used.

Most semiconductor junction temperature sensors use a diode-connected bipolar transistor (by short-circuited the collector-base junction). A constant current passed through the base-emitter junction produces a junction voltage between the base and emitter ( $V_{BE}$ ) that is a linear function ( $V_{BE} = f(T)$ ) of the absolute temperature ( $T$ ). The overall forward voltage drop has a temperature coefficient of approximately  $2 \text{ mV}/^{\circ}\text{C}$ .

When compared to a thermocouple or a resistive temperature device (RTD), the temperature coefficient of a semiconductor sensor is larger but still quite small. Also, the semiconductor sensor's forward voltage has an offset that varies significantly from unit to unit. However, the semiconductor junction voltage vs. temperature is much more linear than that of a thermocouple or RTD. In addition to the temperature-sensing element, circuitry is easily integrated to produce a monolithic temperature sensor with an output that can be easily interfaced to a microcontroller and to provide features that are useful in specific applications. For example, by using an embedded temperature sensor with additional circuitry, protection features can be added to integrated circuits (ICs) (Fraden, 2014).

Electronic platforms open – source offer users the possibility to create its own hardware structure based on a core developed around a microcontroller. Their usefulness is essential in the realization phase, and especially in prototyping phase of the technical systems requiring a central processing unit like microcontroller type (Oxer and Hugh, 2010).

In order to achieve the virtual instrument that we propose in this paper we used the Arduino platform. This is a development board achieved in various configurations, every of these using various microcontrollers ATmega and can be used for building digital devices and interactive objects that can sense and control physical devices. The software component of the platform is integrated into a graphical user interface (GUI), IDE type, which is based on programming language named Processing (Durfie, 2008).

---

\* Corresponding author. Tel.: +40-722-489-401  
E-mail address: nicolaepatrascoiu@upet.ro.



## 2. Integrated temperature sensors LM 9402x

The integrated circuits LM9402x, (LM94021, LM94022, LM94023) built in CMOS technology, integrates a temperature sensor and signal processing circuitry to provide an analog precision output signal that is dependent on the temperature of the capsule.

For temperature monitoring, this application uses the LM94021 sensor manufactured by Texas Instruments and is available on the LM9402xEVM Evaluation Module (EVM) with the same manufacturer. It is usable for a wide range of temperatures between -50 °C and + 150 °C, providing an output voltage that is inversely proportional to the measured temperature. It operates with a single-pole supply voltage starting from 1.5V and the low current required for the LM94021 circuitry makes it ideal for battery-powered systems as well as for general temperature sensing applications.

With two logic inputs, Gain Select 1 (GS1) and Gain Select 0 (GS0), it is possible to select the slope, i.e. the value of the output size according to the input voltage, i.e. the voltage-temperature ratio (Texas Instruments Inc., 2013).

The slope selection inputs can be directly connected to the source potential ( $V_{DD}$ ) or to the ground (GND) without the need for pull-up or pull-down resistance, thus reducing the number of components. These selection entries can also be controlled by TTL-compliant logical signals that allow the system to optimize gain during operation or system diagnostics.

For the correct use of the temperature sensor in Fig.1, the pins configuration, the graphical presentation of the transfer characteristics and the slopes corresponding to each of these characteristics are presented. The slopes are chosen via the GS1 and GS0 pins (Texas Instruments Inc., 2013).

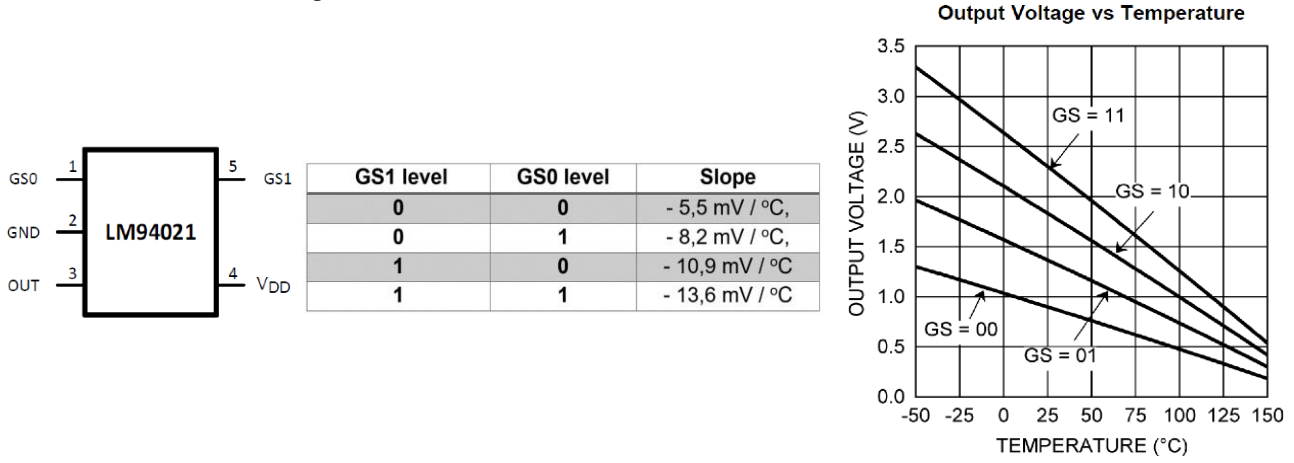


Fig.1. Typical transfer characteristics of the LM 94021 sensor

Although the LM94021 sensor response has a very good linearity is not perfectly linear, the response is slightly parabolic. The shape of the operating characteristics presented in Fig.1. is approximately linear.

The actual operating features are tabulated and can be used in applications built with this sensor by the "look-up table" method. Output voltage values expressed in mV for all 4 selectable sensitivities and for the full range are available to download at [http://www.ti.com/lscs/ti/analog/temperature\\_sensor.page](http://www.ti.com/lscs/ti/analog/temperature_sensor.page).

The static characteristics can be expressed and analytically based on the next parabolic equations defined for the 4 slopes as follows:

$$\text{For } GS1 = 0 / GS0 = 0 \quad V_{TEMP} [mV] = 870,6mV - 5,506 \frac{mV}{^{\circ}C} \cdot (T - 30^{\circ}C) - 0,00176 \frac{mV}{^{\circ}C} \cdot (T - 30^{\circ}C)^2 \quad (1)$$

$$\text{For } GS1 = 0 / GS0 = 1 \quad V_{TEMP} [mV] = 1324,0mV - 8,194 \frac{mV}{^{\circ}C} \cdot (T - 30^{\circ}C) - 0,00262 \frac{mV}{^{\circ}C} \cdot (T - 30^{\circ}C)^2 \quad (2)$$

$$\text{For } GS1 = 1 / GS0 = 0 \quad V_{TEMP} [mV] = 1777,3mV - 10,888 \frac{mV}{^{\circ}C} \cdot (T - 30^{\circ}C) - 0,00347 \frac{mV}{^{\circ}C} \cdot (T - 30^{\circ}C)^2 \quad (3)$$

$$\text{For } GS1 = 1 / GS0 = 1 \quad V_{TEMP} [mV] = 2230,8mV - 13,582 \frac{mV}{^{\circ}C} \cdot (T - 30^{\circ}C) - 0,00433 \frac{mV}{^{\circ}C} \cdot (T - 30^{\circ}C)^2 \quad (4)$$

### 3. Hardware structure

An Arduino Uno open source platform is used to acquisition and primary process of the signal from the sensor. In Fig.2 the block diagram of the monitoring system is presented.

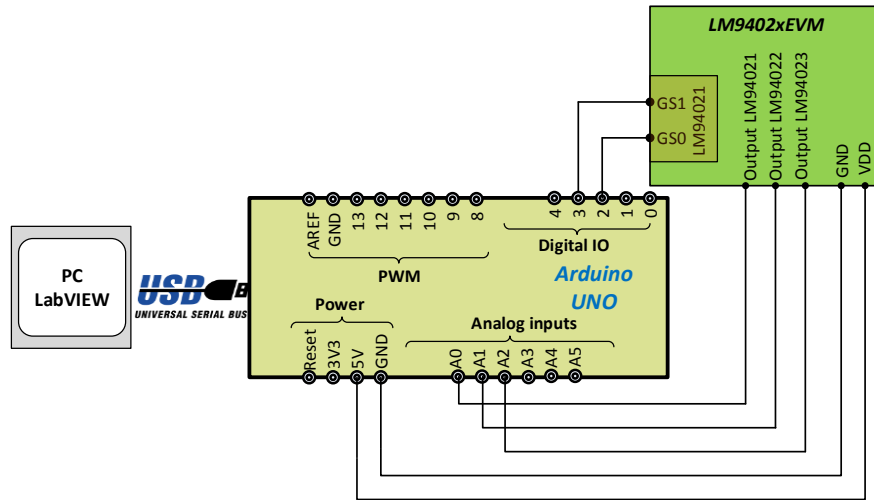


Fig.2. Hardware structure

Information about the temperature value represented by the voltage at the sensor output is taken over by the Arduino Uno module respectively from the analog channel AI0 to which the signal from the sensor is connected. For other analog values, the other analog channels can also be used through a suitable selection.

With the Arduino Uno module, a first signal processing is made, namely its analog-to-digital conversion, for which the integrated microcontroller ATmega328 structure on the Arduino Uno module is used (Evans, 2014).

Through the USB serial interface is obtained a link between a computer and the Arduino Uno module so that the data can be retrieved and processed by means of an application written in LabVIEW. This application provides to the user the data in a synthetic form via an appropriate interface. Also through the same interface user will be able to generate certain commands to the monitored technical system.

The sensor slope control is achieved through two digital channels that allow the user to select any of the four slope values through the application.

#### 3.1. LM9402xEVM Evaluation Module (EVM)

The Texas Instruments LM9402xEVM (EVM) evaluation module, Fig.3 is designed to evaluate the operation mode and performance of the LM94021, LM94022 and LM94023 sensors (Texas Instruments Inc, 2018).

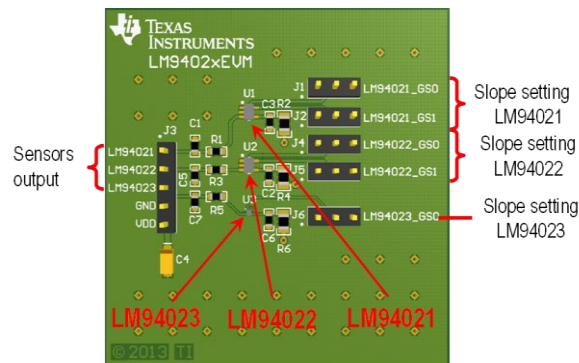


Fig.3. The LM9402xEVM Evaluation Module (EVM)

The Texas Instruments LM9402xEVM (EVM) evaluation module contains all three temperature analogue sensors and all jumpers for setting the slope either by connecting to the V<sub>DD</sub> supply voltage (GS<sub>x</sub> = 1) or by connecting to the GND table (GS<sub>x</sub> = 0). Slope control can also be accomplished by appropriate logic levels taken from the digital channels of the Arduino Uno module and applied on the same jumper. Are used for this the digital IO2 and IO3 pins.

The analog output of the sensor is connected to the analog input AN0 of the Arduino module.

## 4. Virtual instrument

The virtual instrument is the application and represents the program written in LabVIEW, with which the communication with the Arduino Uno module is managed, and the processing of the data received from the sensors via the Arduino module is performed.

### 4.1. Front panel

On the front panel there are user interface elements that can be used to:

- entering data or commands (input elements) called controls;
- displaying the results obtained by processing data called indicators.

In Fig.4 there are shown the snapshots of the front panel of the virtual instrument corresponding to its operation.

In the realization of this application, three windows of the front panel are used, the user having the choice of any at any time of them. The three windows named **Grafic**, **Tabel** and **Statistica** can be selected using the Tab command.



Fig.4. Snapshots of the front panel

The **Grafic** window is used to display the time evolution of the monitored temperature values. The time units on the abscissa are the real-time units, represented by the date, time, minute, and second corresponding to the reading of the respective temperature value by the sensor.

The **Tabel** window is a table representation of these temperature readings and their reading times

The **Statistica** window shows the maximum value found throughout the temperature acquisition as well as the time of its identification.

Also on the front panel are the following indicators:

- **Tensiune** - a numeric type indicator showing the volt value of the voltage read from the sensor;
  - **Temperatura curenta** - slide indicator showing the value of the current temperature in degrees;
  - **Alarma 1, Alarma 2, Alarma 3** - Boolean indicators indicating that the set alarm thresholds have been exceeded
- The controls on the front panel with their defined functions are:

- **Portul Serial** - ring control used to select the USB port to which the Arduino Uno module is connected;
- **Canalul analogic** - numerical control used to select the analog input to which the sensor to be read is connected;
- **Sensibilitate** - ring-type control used to select one of the 4 slopes of the sensor.
- **Setpoint 1, Setpoint 2, Setpoint 3** - numerical controls used to set alarm thresholds.
- **STOP** - boolean control used to stop the program running

#### 4.2. Diagram block

The block diagram is the proper program and consists of operations, functions and programming structures arranged according to the data flow necessary to execute the program (Sumathi and Surekha, 2007).

Running the program is done as long as the **STOP** button on the front panel is not actuated, and this operation is given by including all operations and functions in a While structure. Between two consecutive cycles of this structure, a delay of 1 sec is set by using the *Wait Until Next ms.vi* function so that the acquired temperature values with one read per second. Is used the *Open Serial.vi* function that open a serial communication with the LINX-controlled module, in this case the Arduino Uno module, and *Close.vi* function, respectively, that shut down communication with the LINX-controlled module and release the computer's connection resources. The activation of the two functions takes place when the program starts running after the **STOP** button is activated.

The general block diagram of the virtual instrument is presented in Fig. 5.

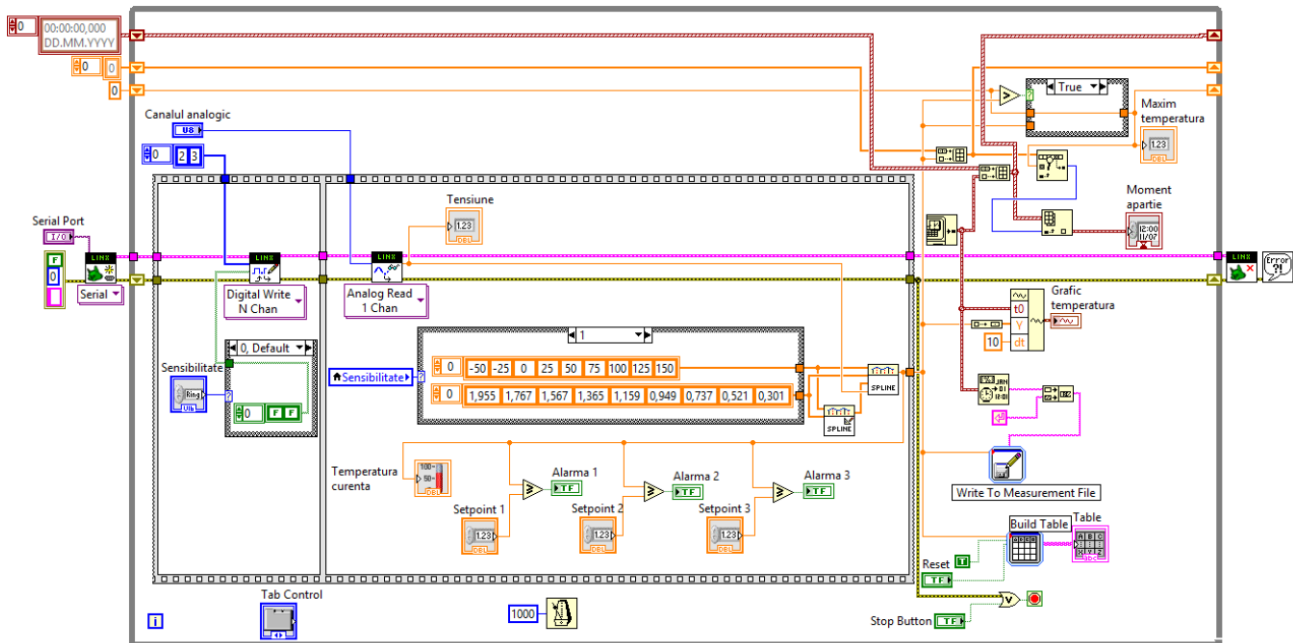


Fig.5. Block diagram of the virtual instrument

By using the *Sequence* structure, data acquisition and processing takes place in two sequences, as follows:

1. The slope value is selected by using the *Digital Write.vi* function that sent through selected digital outputs the proper code to the selection pins GS0 and GS1;
2. The voltage value is read from the sensor by using the *Analog Read.vi* function and the voltage-temperature conversion is made after that.

With the values of the voltage read from the AN0 analog input for the voltage-temperature conversion, the relations (1) ... (4) or the "look-up table" can be used.

In this application, for the conversion voltage-temperature was chosen a method that does not involve significant memory allocation and is valid across the entire range of the transducer. An interpolation method has been chosen for only a few of the voltage-temperature pairs from the sensor catalog.

The *Spline Interpolant.vi* and *Spline Interpolation.vi* functions are used for a small set of value pairs from the sensor catalog for each slope, as shown in Fig 6.

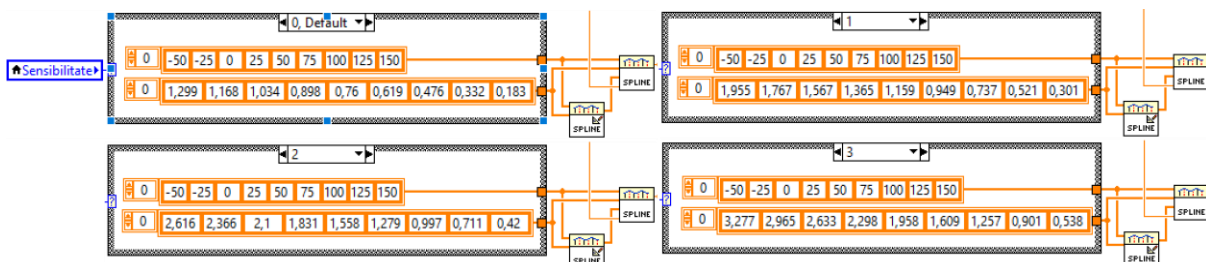


Fig.6. Voltage – temperature conversion for all four slopes

The *Spline Interpolation.vi* function returns a temperature value by the spline interpolation. The current temperature corresponds to the values of the read tension and the values obtained at the output of the *Spline Interpolant.vi* function that return an array with the length of the number of values and containing the second derivative of the spline  $g(x)$  at the tabs of the read tension.

During the acquisition, the maximum value of the temperature and the moment of its occurrence are identified in each reading cycle by using the *Shift Register* operation. With this transfer operation between consecutive cycles, the maximum value identified in a cycle with the new read value is compared and the maximum between them is kept.

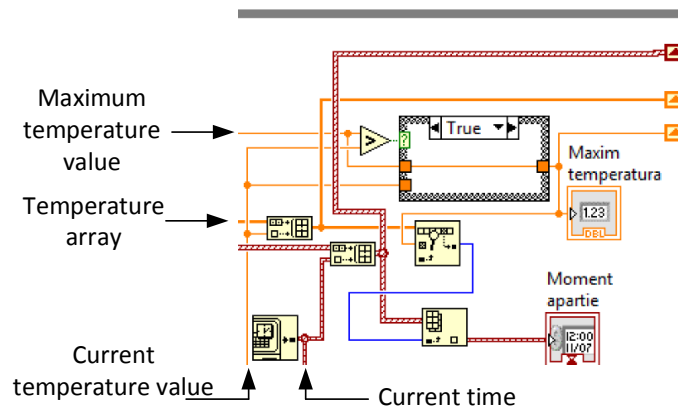


Fig.7. Identifying the maximum temperature

At the same time, the values read in each cycle are grouped and indexed into a vector so that for each maximum of the temperature values its vector index is also identified. Simultaneously with the temperature values are indexed and their time moments and using the index of the maximum temperature can be found and the time of reading this value.

The readings values of the temperature can be exported in a *.lvm* format to a file that can be later opened in an Excel spreadsheet and used to keep a history of the measured sizes. For this, *Write To Measurement File Express VI* function is used. This function performs the data entry in text-based measurement files (*.lvm*), binary measurement files (*.tdm* or *.tdms*) or Microsoft Excel files (*.xlsx*).

## 5. Conclusions

Following the obtained results, it can conclude that this virtual instrument can be used to acquire the temperature values with high measurement speed and precision selected through selected slopes.

The fastest of the tested sensors is the LM 94021, with the linearity being very good, the other sensors being slower but the conclusions being valid for them as well in terms of precision.

Data is stored in an external Excel file and further processing is possible.

Similarly, implementation can be done on other sensors with low time response (humidity sensor, atmospheric pressure sensor, etc.)

## References

- Durfee W., *Arduino Microcontroller Guide*, University of Minnesota, [www.me.umn.edu/courses/me2011/arduino/](http://www.me.umn.edu/courses/me2011/arduino/), (2009).
- Evans W.B. *Arduino Programming Notebook Creative Commons*, San Francisco, (2014).
- Fraden. J., *Handbook of Modern Sensors. Physics, designs, and applications*. Third edition. Springer-Verlag New York, (2014).
- Oxer J., Hugh B., *Practical Arduino. Cool Projects for Open Source Hardware*, Springer-Verlag New York, (2010).
- Sumathi S., Surekha P., *LabVIEW based Advanced Instrumentation Systems* Springer-Verlag Berlin Heidelberg, (2007).
- Texas Instruments Inc., *LM94021/LM94021Q Multi-Gain Analog Temperature Sensor*, Dallas, USA (2013).
- Texas Instruments Inc., *LM9402xEVM Evaluation Module (EVM). User's Guide*, Dallas, USA (2018).
- Arduino Compatible Compiler for LabVIEW-Version 1.0.0.19*, TSXeperts Alledine, (2015).

# A mobile system based on LiDAR technology used for data acquisition in traffic management

Cosmin Rus<sup>a\*</sup>, Nicolae Pătrășcoiu<sup>a</sup>

<sup>a</sup>University of Petrosani, University Street 20, Petrosani 332006, Romania

---

## Abstract

This paper we propose a solution to realize of a mobile system for traffic management by counting the number of vehicles on a road with one or two lanes. The traffic intensity is measured using the transducers based on LiDAR principle. The acquired data are local stored into a local data logger and simultaneous are transmitted via radio communication to a dedicated server. The novelty of this system is represented by the communication facility provided by the new LoRa technology. LoRa is a long-range wireless telecommunication system with low power and low data rates promoted as an Internet-based object (IoT) infrastructure solution. End devices (end-nodes connected to various sensors) use LoRa on a single wireless network to communicate with Internet-connected gateways that act as transparent links and allow messages to be sent between these end devices and a network server central. This paper also provides an overview of the LoRa wireless telecommunication system and an analysis of its functional components. System performance is evaluated by field tests and simulations. Based on the analyzes and evaluations, some solutions for monitoring and controlling processes are proposed using this communications infrastructure. Also, it is highlights that this system is mobile and it is not invasive on the road structure.

*Keywords:* LoRa; data acquisition; non-invasive technology; urban traffic management; LabView.

---

## 1. Introduction

In recent decades there has been a steady increase in the number of private cars in traffic, while public transport is steadily declining. The current road infrastructure no longer meets the demands. Accidents and congestion caused by traffic have an important impact on life, reduce productivity and reduce energy. Traffic congestion, which causes environmental problems and accidents, is becoming increasingly acute. The benefits of transport are diminished by the increasing number of negative impacts (air pollution and accidents, increased stress on road users), resulting in a vicious circle in urban transport. The spectacular increase in road traffic can't be met in the short term by a corresponding increase in road space. For this reason, in all developed economic environments, two-directional solutions were dealt with: improving the design of road space to increase utilization and improving the parameters of the traffic through control and monitoring. Developing an intelligent transport system requires the collection of high-quality and real-time information about the traffic flow. Increasing pressure to improve the traffic management, the collection of traffic data methods has evolved considerably, and the access to real-time traffic information becomes usual (Steinset, 2004).

For planning the road development or the management of traffic it is very important to collect the traffic data and use them in anticipation of traffic volume. The traffic flow can be considered as a function having a random distribution because it differs from many parameters including the time of day for measurement, season, geographical position, environmental conditions. It follows that the data collected is a methodological statistic and, despite such complexities, it follows some well-defined models that can be classified and analyzed. Thus, the collection of traffic data can be done in different ways and plays an important role in the evaluation and management of road networks (Massa et al., 2008). Generally, the traffic flow consists of vehicle count on the road and the technologies used for this can be split into two categories: the intrusive and non-intrusive.

The intrusive methods consist of transducers which are placing on or in the road and a data recorder. The most usual transducer used in intrusive methods are: pneumatic road tubes, piezoelectric and almost inductive loops. For all of them, it is necessary to bury in the construction layers of the road, becoming fixed or permanent installation.

---

\* Corresponding author. Tel.: +40765744436.  
E-mail address: cosminrus@upet.ro.



The non-intrusive techniques are based on the remote data recording. Eliminating the manual counting that is often used, new technologies use transducers based on passive and active infrared, microwave radar, ultrasonic and passive acoustic, or video image detection.

## **2. Lidar sensors**

To achieve the system, Lidar sensors have been selected due to their some features, such as influence reduced of the dust or ambient light, the operation is not influenced by the color or optical transparency of the reflective surface.

Small dimensions and low power consumption make this sensor ideal for projects where energy sources are batteries and energy consumption should be as low as possible. The sensor can be used for drones, robotics, 3D image scanning, collision avoidance, fluid / solid level measurement, medical imaging and more. This device measures the distance by calculating the delay between transmitting an infrared laser signal and receiving it after reflecting at a target meeting. This delay translates away using the known lightning speed. The sensor transmits through the laser beam a coded signature and searches for that signature in the reflection of the signal, allowing for an extremely efficient detection. Signal processing techniques are used to achieve high sensitivity, speed and accuracy using a low power source and a low-cost system.

To perform a measurement, this sensor first performs a receiver polarity correction, correcting the change of ambient light level and allowing maximum sensitivity.

Then the device sends a reference signal directly from the transmitter to the receiver. Store the transmission signature, set the delay for the "zero" distance and recalculate this delay periodically after several measurements.

Then the device initiates a measurement by making a series of data acquisitions. Each acquisition is a transmission of the main laser signal while recording the return signal to the receiver. If there is a signal match, the result is stored in memory as a correlation record. The next purchase is summed up with the previous result. When an object at a certain distance reflects the laser signal back to the device, these repeated acquisitions cause a peak of signal coming out of the "noise" area at the corresponding location of the distance from the correlation record.

The device integrates purchases until the peak of the correlation record signal reaches a maximum value. If the returned signal is not strong enough for this to occur, the device stops from making purchases.

The signal strength is calculated from the magnitude of the signal recording peak and from a valid signal, the reference threshold is calculated from the noise level. If the tip is above this threshold, the measurement is considered valid and the device will calculate the distance, otherwise it will report 1 cm. From the next measurement, the sequence is resumed.

At startup or reset, the device performs a self-test sequence and initializes all registers with the default values. Approximately 22 ms the distance can be taken with the I2C interface.

This device has a serial interface compatible with I2C. It can be connected to an I2C bus as a slave device under the control of an I2C master.

The I2C circuit works internally at 3.3 V. An internal level switch allows the device to run at a maximum of 5 V. The 3k ohm pullup internal resistances provide this functionality and allow easy use and easy connection to the I2C host.

The device has a 7-bit slave address with a default value of 0x62. The 8 bit write address I2C is 0xC4 and 0xC5 for reading.

After initializing the system, the most significant bit of the I2C address byte is set to automatically increment the register address with successive reads or writes in a transfer data block. This is commonly used to read the two bytes of a 16-bit value in a single transfer and is used in the following example.

## **3. Local data acquisition**

The hardware structure of the mobile system is represented in Fig. 1 and consists of the following:

- Arduino Uno/Nano development board;
- Lidar Lite v3 sensor connected to Arduino digital inputs;
- ESP32 a low-power system on a chip (SoC) with Wi-Fi and dual mode Bluetooth capabilities, that is connected to the Arduino between a serial communication bus;
- A simple local LCD display also connected to the Arduino between a serial communication bus;

The LiDAR sensor will be connected according to the technical specifications to the Arduino module either using an I2C connection or using a PWM connection. The ESP32 will connect to Arduino using a serial connection and will allow the retrieved information to another module or to a LoRa gateway. The LCD display allows you to display information on the number of vehicles on a traffic arc, thus testing the entire system to the specified parameters. The entire system will be powered either from the power grid where it is possible or from an external battery in case of necessity. In the future, it is also desirable to create a power system using other types of renewable energy. ESP32 module allows communication using wireless communication protocol LoRa and so these modules can be integrated simply in any equipment regardless of its physical size tends to be minimized and a more reliable all components.



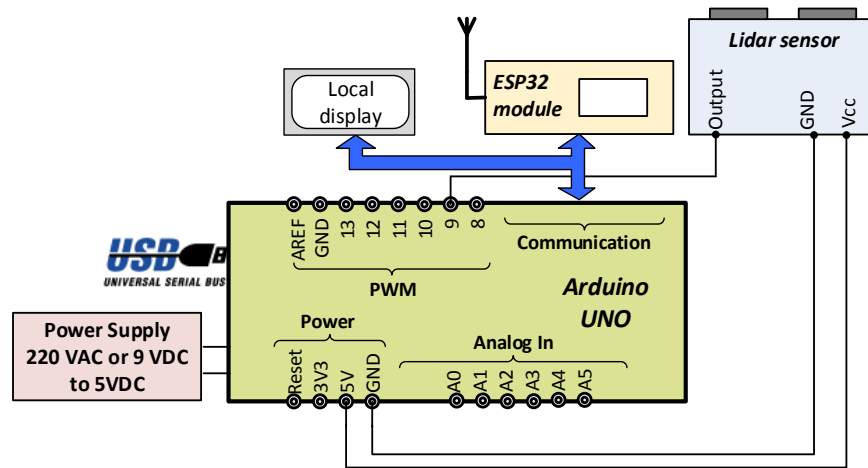


Fig. 1 Hardware structure diagram

For this system the supply voltage is provided from an alternative voltage source or from a battery through the 5 VDC controller on the Arduino board. In this way, the autonomy of the system can be assured. The monitoring system using a Lidar sensor, in addition to allowing for special portability, also ensures a fast and secure acquisition of data in traffic management (the number of machines crossing an intersection, their speed, distance measurements). Laser scanning of the Lidar type has other applications in many areas of activity. LiDAR laser scanning provides an interactive topographic map with a height accuracy of up to 20 cm. Current data has an accuracy of up to 1.5 m. As a complement to topographic measurements, technology can be used to build roads, other construction sites, etc. It can also be used to evaluate different alternatives in the field of construction, education and research, engineering.

Since LiDAR is based on air scanning, the system is able to scan large areas of land in a relatively short time. An aircraft / helicopter mounted LiDAR system can scan a 300 km<sup>2</sup> area with a precision of 0.15 m over a 4-hour flight. Unlike photogrammetry involving manual, time-consuming work, LiDAR processing is largely automatic, with the possibility of obtaining the land model within weeks and not months after obtaining the data.

LiDAR is an automated system and does not involve a prior objective visit. Topographic maps can be obtained even in less accessible areas with reduced visibility and complexity at ground level.

Fast and automatic data collection for LiDAR allows designers to consider a multitude of options and alternatives in the design that will be performed. It also allows them to study alternative routes to suggest to the beneficiary. Normally, only 3-4 flights will be required to get a precise representation of the land and buildings, respectively alternate routes in an area with increased complexity. The optimal option will then be selected to meet the expectations of the beneficiary.

LiDAR is able to penetrate dense vegetation, which means that the team of designers can get information from hard-to-reach areas much faster and more accurately.

The experimental model setup is shown in Fig.2.

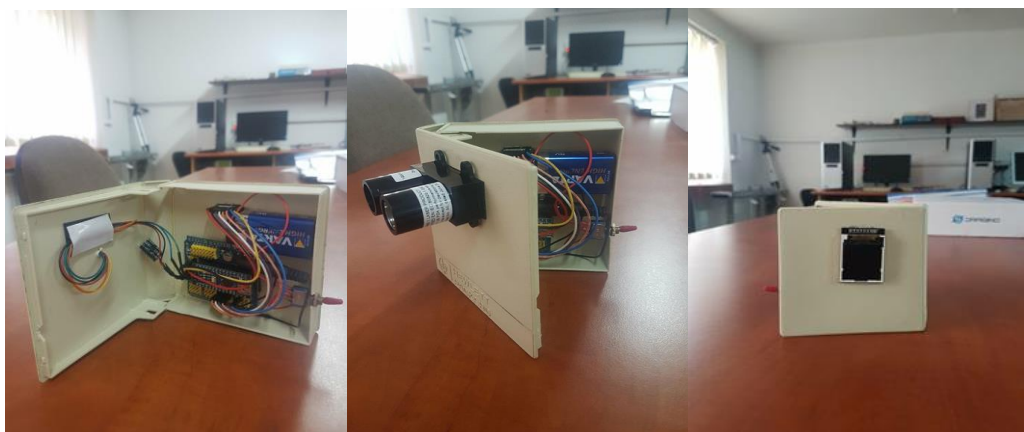


Fig. 2 Experimental model setup

The sensor is used to count vehicles on a lane at a time. Calculate the distance from the sensor to a particular reference point between it and the sidewalk, or consider the maximum distance that can be measured with this type of sensor when another value is found count a vehicle. The resulting number of counting vehicles on lane is locally displayed through a local LCD display and also are sent to the ESP32 radio module. Through this module, the information can be sent by radio transmission in 2.4 GHz band to long distance till a LoRa (Long Range Wireless Network) gateway connected to a network server from where it can be taken through internet network.

#### 4. LoRa network

The term LoRa (or LoRa technology) refers to a category of high-power low power long range radio communications. Unlike conventional digital radio transmission technologies, LoRa technologies have the capability of communicating data over miles of miles or even tens of kilometers, with extraordinary applicability in wireless sensor networks, the Internet of Things (IoT), and networking of smart devices. Behind the term LoRa is actually a multitude of proprietary or open technologies, similar to functionality but totally incompatible as implementation - the field of long distance radio communications is currently in a pioneering phase in which standardization stability and technological interconnection methods are a far-reaching goal. Other terms used to refer to high-bandwidth digital radio networks are LoRaWAN (Low Range Power Network), LPWAN (Low Power Wide Area Network), Low Power Network (LPN). Some of these terms are registered as brands belonging to certain companies or consortia being used to identify a particular LoRa technology (even the term LoRa is a registered trademark of Semtech). LoRaWAN is a radio transmission protocol capable of forms a smart grid. The setup network uses a star-of-stars topology, with gateways serving as transparent bridges that transmit information between sensors and the central server. Gateways connect to the network through traditional IP connections, and sensor devices use single-pass wireless communications for one or more gateways (Dongare et al., 2017).

The structure of LoRa network is similar to one cellular network, but instead of having a single interconnected network, LoRa allows the deployment of more independent networks over the same infrastructure (Sanchez-Iborra et al., 2016).

LoRa can covers 15-20 kilometers. The compromise for such a distance is a reduced power and a lower bit rate, about 0.3 to 50 kbps.

The elements components of the system structure in "end-to-end" way of LoRaWAN are shown in Fig.3 and these are:

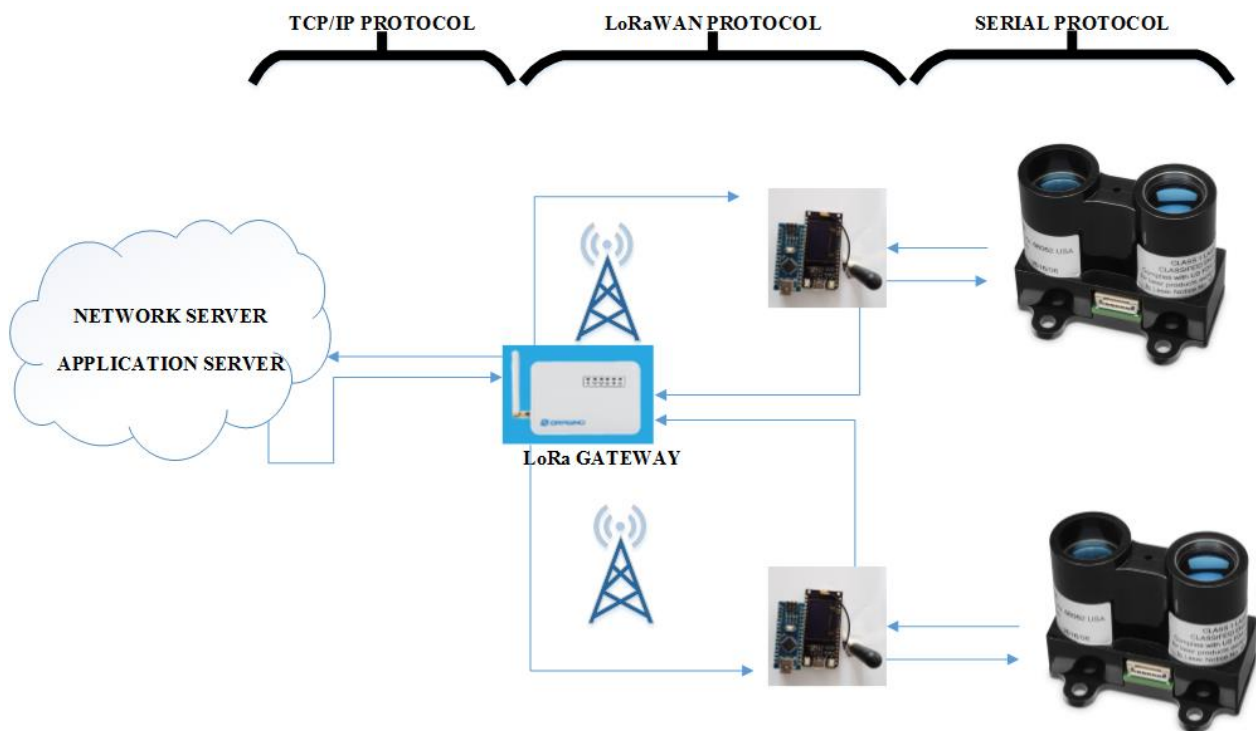


Fig. 3 The architecture of LoRa system

#### Nodes

Represents the elements of the LoRa network that monitors and controls the infrastructure devices which are usually located at distance, the ESP32 - LoRa - OLED (Fig. 4) which transmit the data taken from the LiDAR sensors via an Arduino Nano development board in this case. The ESP32 - LoRa - OLED has a 0.96 inch blue OLED display for displaying local information and a Lora transceiver, the SX1276 transceiver for the 868 MHz band. It has a high sensitivity over -148dBm, + 20dBm output power, high reliability and long transmission distance. The onboard Wi-Fi antenna, lithium battery charging circuit, CP2102 interface and USB serial chip, make it the perfect support for Arduino development environment (Espressif Systems, 2015).

Operating voltage is from 3.3V to 7V. It have support for Sniffer software protocol analysis, Station, SoftAP, and Wi-Fi Direct modes. Data rates are comprised between: 11 Mbps and 150 Mbps and the transmit power is between 15.5 dBm and 19.5 dBm. This development board has a receiver sensitivity up to -98 dBm.



Fig. 4 ESP32 - LoRa – OLED development module

### ***LoRa Gateway***

This is the device that receives data from network nodes (ESP32) through the LoRaWAN protocol and then is transferred over the Internet to the main application server. The connection to the application server may be Ethernet, GSM data, or any other cable or wireless telecommunications connection that provides an Internet connection. In fact this base stations (LoRa Gateway) are connected to the network server using standard IP connections. In this way, the data uses a standard protocol that can be connected to any public or private telecommunications network. Given the resemblance of a LoRa network with a mobile network, the LoRa base stations can often be integrated into a cellular base station. In this way, the unused capacity of the cellular station can be used to transmit the data to the network server (Sornin et al., 2017).



Fig. 5 Dragino LoRa gateway used for system

### ***Network server***

The network server manages entire LoRa network. The network server acts to remove duplicate packets, recognition programs, and control the data transmission speed. Given the way it can be deployed and connected, the complexity of implementing a LoRa network is very low.

### ***Application server***

From the application server that is installed on the network server, we can access applications that retrieve data from network nodes through the gateway and display them to provide the most relevant information for the client. In addition, LoRa allows bidirectional communication between nodes and the network server, remote commands can be sent to the nodes, these commands can be related to node management (remote software update) and control of elements in a system (change of green time of traffic lights).

## 5. Conclusion

The realization of this mobile system of counting the number of vehicles crossing a road artery from an urban center is the first step in the direction of developing a traffic management system. The most important feature of this system is that it does not use invasive techniques on vehicle runways and can easily be moved from one location to another location. Through the LoRa network, real-time data can be obtained on the car traffic characteristics of the monitoring points, thus obtaining sufficient data to formulate new directions for the development of the automotive infrastructure plans. LoRa is a long-range telecommunication and low-power telecommunication system for the "Internet of Things". The physical layer of the entire system uses the LoRa module, a proprietary technology with a MAC protocol. LoRaWAN is an open standard with the specifications available for free. This paper provides an analysis of the bidirectional operation of the LoRa protocol on an experimental platform specifically designed to study the performance of the network, documented in this paper. The results obtained during the preparation of this paper show that LoRa modulation, due to modulation of spectrum dispersion and high sensitivity of the receiver, offers good interference resistance. Field trials demonstrate that LoRa can provide satisfactory network coverage of up to 3 km on a network in a suburban area with not very dense residential dwellings. LoRa is therefore suitable for low power, low speed and long range. The experimental results also show that the protocol is reliable and very simple to implement.

## References

- Adelantado F., Vilajosana X., Tuset-Peiro P., Martinez B., Melià-Seguí J. and Watteyne T., *Understanding the Limits of LoRaWAN*, IEEE Communications Magazine, (2017).
- Bankov D., Khorov E., Lyakhov A., On the Limits of LoRaWAN Channel Access, 2016 *International Conference on Engineering and Telecommunication (EnT)*: 10–14. doi:10.1109/ent.2016.011, (2016).
- Dongare A., Hesling C., Bhatia K., Balanuta A., Pereira R. L., Iannucci B., Rowe A., OpenChirp: A Low-Power Wide-Area Networking architecture, 2017 *IEEE International Conference on Pervasive Computing and Communications Workshops (PerCom Workshops)*, pg. 569–574, (2017).
- Espressif Systems, *ESP32 Series Datasheet*, [http://espressif.com/files/documentation/esp32\\_datasheet\\_en.pdf](http://espressif.com/files/documentation/esp32_datasheet_en.pdf), (2015).
- Leduc G., *Road Traffic Data: Collection Methods and Applications*, European Commission-Institute for Prospective Technological Studies, JRC, (2008).
- Massa P.D., *Choosing an Ultrasonic Sensor for Proximity or Distance Measurement*, Sensor Magazine, (2008).
- Sanchez-Iborra R., Cano M.D., *State of the Art in LP-WAN Solutions for Industrial IoT Services*, <http://www.mdpi.com/1424-8220/16/5/708>, (2016).
- Sornin N. et al., *LoRaWAN 1.1 Specification*, <https://www.lora-alliance.org/lorawan-for-developers>, (2017).
- Steinset B.K., *Traffic Data Collection and Analysis*, Ministry of Works and Transport, ISBN 99912-0-417-2, (2004).

## Design of a computer game for BCI systems

Sebastian-Daniel Rosca<sup>1\*</sup>, Monica Leba<sup>2</sup>

<sup>1</sup> Ph.D. Student Eng., University of Petrosani, Str.Universitatii, nr.20, 332006 Petrosani, Romania

<sup>2</sup> Prof. Ph.D. Habil., University of Petrosani, Str.Universitatii, nr.20, 332006 Petrosani, Romania

---

### Abstract

The Computer Brain Interface (BCIs) is a new type of user interface designed to recognize real-time user-specific intentions based on user brain mapping. Gradual advancing technology behind the BCI interface has made it possible to develop gaming applications that use directly brain input instead of well-known traditional control methods. This paper presents the Mental Pool Game, a brain-controlled computer game powered by Unity3D, which uses a commercial BCI device based on a network of electroencephalography (EEG) sensors placed on the scalp capable of creating brain patterns only by capturing conscious thoughts from a user that can be easily reproduced as mental actions to control strength and speed on which the user can project on the white ball to hit any of the eight balls on the pool table.

*Keywords:* BCI; EEG; video games

---

### 1. Introduction

Over the past decades, there was an exponential improvement in imaging technologies that allow researchers to assess cognitive workload, short-term memory and space / navigational behavior in humans. Using new experimental paradigms and brain imaging devices, researchers get a deeper insight into neural correlations of emotion, knowledge and engine control.

Brain-Computer Interface (BCI) combines two fundamental research areas: Neuroscience and Human-Computer Interaction (HCI) that serve as a link bridge that allows users to interact with the computer based on commands transmitted directly from the brain to the standard input of the computer (Vasiljevic et. al., 2018).

BCI systems use different neuroimaging sensors to retrieve evoked brain signals through a specific thinking process that corresponds to a certain mental state of the user at a time that can be converted into a computer command. In order to provide a general overview of sensory, motor and cognitive processes, the BCI system uses the electroencephalogram (EEG) principle to measure electrical activity of the brain, which is diffusely distributed across the scalp and that corresponding to brainwave: alpha, beta and theta (Galway et. al., 2015).

### 2. BCI related to games

Nowadays the increase in the accessibility of computer systems among the population and also the advancement in computing technology that is able to offer computers with more computing power and with an advanced 3d computing graphics has pushed the video game industry to become a major industry that engage specialists from many sub-disciplines to be able to provide an improved user experience in game play that become a new way of life able to improve task management, simulation and learning activities.

---

\* Corresponding author. Ph.D. Student Eng., Sebastian-Daniel Rosca  
E-mail address: sebastianrosca91@yahoo.com.

As far as brain-controlled video game technology is concerned, it can be used for both medical and non-medical purposes: to recover limb motricity in case of brain level trauma or in case of suffering by a neurologic disease such as stroke or severe neurodegenerative disease using generation of motor imagery based on BCI commands; as assistive technology for person with mobility impairment such as spinal cord injuries who otherwise are not able to perform game controls; for relaxation and entertainment using in many case to measure the concentration level of a player (Rosca and Leba, 2018, Anwar et. al., 2018 and Belkacem et. al., 2015).

The main concern in developing video games based on the BCI interface is to achieve a natural user interaction with the game environment capable to motivate the user both by implementing of some intuitive controls and by transmitting some entertaining and challenging experiences because the result of implementing a BCI system is dependent of user engagement.

Research in the field of video games, even in the case of BCI technology, has shown that rational playing of video games brings a benefit in the life of the player by acquiring new knowledge, experience and skill improvement given by certain cognitive processes that it involves during playing games such as: problem solving, remembering and training sessions (Vourvopoulos et.al., 2017).

Continuous growth of the video game industry driven by the development of Virtual Reality (VR) and the development of rapid game prototyping tools allowed the integration of the BCI interface into games development that can help the research environment like: Games as stimulus developed for studying human behavior; Games as means of training; Games able to evaluate performance metric of users (Kerous et.al., 2018).

A BCI interface uses electroencephalography (EEG) as an access point to detect and record the activity of neurons by creating a pattern of brainwaves that is generated by conscious thoughts that can then be analyzed by a computer and converted into brain-controlled commands applicable as inputs for a game.

Using the electroencephalogram principle in games designed to evaluate metric performances as a result of analyzing the data acquired for a particular user can be obtained measurements of his performance indices like: cognitive workload, level of stress, arousal, task engagement and level of relaxation (McMahan et.al., 2015).

With regard to the processing of EEG segments, this is not an easy task. A major common problem is that mental imaging operation used as entry for game control varies from one person to another on the one hand because the brainwave pattern obtained from the mental drive training session is unique for each person, requiring a training session for each user and on the other hand due to variables such as: attention, emotion, focusing on thought and hand grasping imagination (Diamal et. al., 2017).

In terms of brain activity analysis during video game play using the BCI interface, the major brainwave frequencies that present interest are: Alpha brainwave (7.5 -12 Hz) that reflects the relaxation level of the user and Beta brainwave (12 – 30 Hz) that corresponds to the level of attention, concentration and vigilance of the player during play games. The research in gaming domain based on BCI interfaces has demonstrated that Beta rhythm magnitude it growing in amplitude when the player needs to navigate into game environment, because this activity it based on extra level of concentration from user. The same things are observed in the situation in which the player must avoid hazard moments or when it must focus to survive from enemy attacks (McMahan et. al., 2015, Diamal et. al., 2017 and Bakaoukas et. al., 2016).

### **3. Software**

#### *3.1. Unity3D Gaming Engine*

Unity is an open source cross-platform game engine developed by Unity Technologies. It is a developer-oriented platform that allows: the development of 2-dimensional and 3-dimensional desktop applications for both Windows and Linux operating systems; mobile app development for Android OS and iOS operating system; development of console games (Posen, 2018).

The three-dimensional version of the Unity platform known as Unity3D includes a number of complex components useful to game developers such as: component mesh, component physics, rendering component, audio component and script component etc.

Unity3D also offers a wealth of resources from common ground scripts to common scripts to useful collision detection tools to create realistic games. As far as the implementation of scripting functions is concerned, Unity3d supports both the C# programming language and the JavaScript programming language both designed to develop high performance multimedia applications and games (Yang et.al., 2015).

#### *3.2. Mental Pool Game design*

In this paper we developed a 3D Mental Pool Game based on Unity3D game engine powered by C# programming language which has been designed for several target user groups, from healthy people to people with disabilities, so they will no longer have to use classical commands that depend on the use of well-known peripheral input devices present on any PC such as a keyboard, mouse or joystick to control the movement of an object on a virtual environment,



in our case to control the strength and speed that the user can project, using only his own brain, on a white ball in order to hit any of the eight balls placed on the pool table using a system based on a BCI interface as presented below:

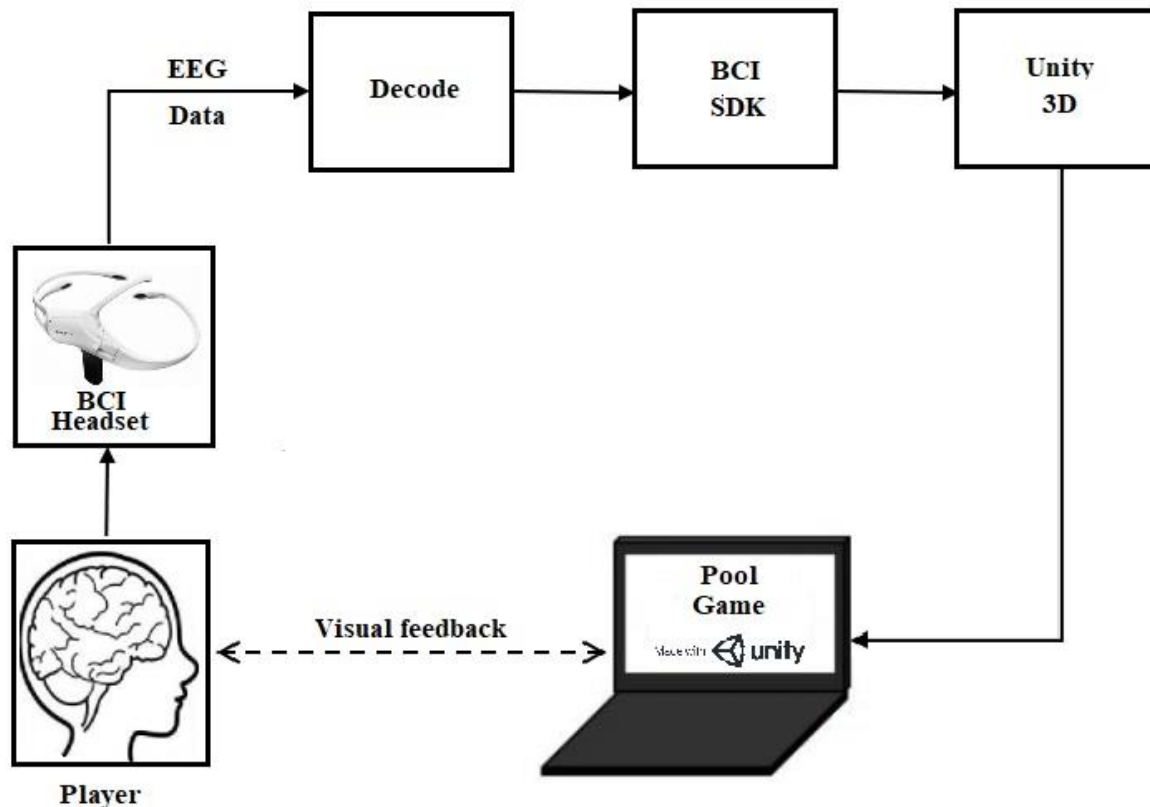


Fig. 1 Block diagram of BCI system design

In fig.1 is shown the functional diagram of the BCI system along with the algorithm for acquisition and analysis of the electroencephalogram signals from the subject and conversion of these signals into mental commands that can be used as inputs to send in the game control commands directly from the brain.

The BCI headset used for acquiring EEG signals from the brain is a commercial version that provides five semi-dry EEG electrodes placed on the scalp level of user and that can detect the activity of the whole region of the brain. Also, the BCI helmet has a 3-axis gyroscope that is used to update the white ball position on the pool table within the game scene according to the user's position by changing the direction of the head movement.

In order to decode the EEG signals from the user of the game, the BCI headset uses a series of analog to digital (ADC) converters to translate the electrical activity of the neurons into a binary form that can be recognized by any computers.

The EMOTIV BCI software development kit (SDK) is used to analyze and detect the user-generated binary commands generated by the game user using the BCI headset and based on a script written in C # programming it can convert them into keypress used as input to give white ball a specific movement speed on the table.

The following is a BCI system operating logic scheme used to control the game in which steps are considered during the design stage.

As can be seen in fig.2 the video game user must first check whether there is a connection between the BCI headset and the computer and in the opposed case the user must act to apply some of saline solution to rehydrate EEG sensors to improve their contact with the scalp that otherwise represents a common problem for non-invasive BCI systems based on semi-dry EEG electrodes.

Also to be able to play Mental Pool Game an user it must to start training session of two distinguish mental commands: Neutral mental command that correspond to neutral state it is used as a reference to distinguish between the conscious thoughts that form the brain pattern that corresponds to a particular action and the signals generated by noise sources such as head movement or due to bad contact of EEG electrode with scalp; Push mental command allows the game user to record the brain pattern on which he focus on an action imagining the forward movement of the white ball on the billiard table. The moment speed of the white ball is variable depending on the cognitive power that the user allocates at certain moment to performing the mental task.



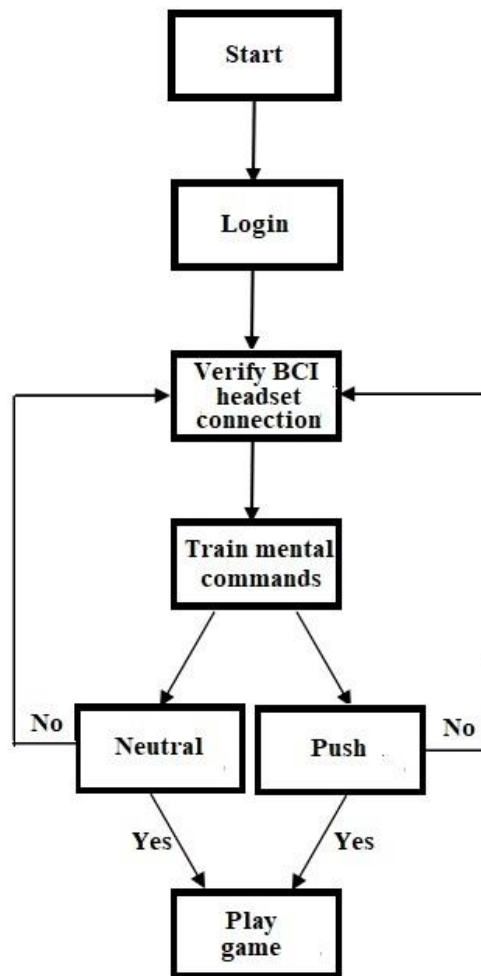


Fig. 2 Logic bloc diagram for BCI system design

The following is the graphical user interface (GUI) of the Mental Pool Game developed by us in the Unity3D platform game engine (fig.3):



Fig. 3 Mental Pool Game GUI

#### 4. Results & Discussions

Three healthy subjects were first familiarized with BCI headset on how mental patterns were formed based on the acquisition of electroencephalogram (EEG) signals during a training session that involved a training of Neutral and Push mental commands within the software development kit (SDK) Emotiv Xavier Control Panel developed by EMOTIV Inc. They had 30 seconds to train each mental command within the graphical user interface and in case of training of the Push mental command during their training session, they were asked to visualize the forward movement of a virtual cube, either directly or following a predefined animation and were able to track on top of the interface via a gauge indicator the own cognitive power that was dependent on the level of focus with which they performed the mental task. After all of the subjects played one round of each game until the exhaustion of the balls on the pool table.

During the experiment, it was found that the force with which the white ball was pushed onto the pool table to strike other balls is directly influenced by the level of attention and concentration that must be maintained throughout the mental load, with the power to concentrate depending on the fatigue of the subjects, the stress conditions, their emotional state, and the level of interest represented by the degree of attractiveness of the game in order to capture their attention.

#### 5. Conclusions

This paper proposed a 3-dimensional game developed in the Unity3D game engine which has been implemented in accordance with physics laws to reproduce a true copy of the real game and whose controls can be driven directly by brain using the EEG signal caption from the user through the BCI interface that is able to convert electrical stimuli in binary form based on a script written in C# programming language that used a series of functions designed for mapping mental commands that are provided by Emotiv BCI software development kit (SDK) to convert binary form of signals into keystroke sequences used as control inputs for game play.

The Mental Pool Game has been designed so that it can be used both for purely recreational purposes by healthy people and for medical purposes especially in the case of people with permanent disabilities such as: severe neurodegenerative disease that cannot have cure, spinal cord injuries or superior limbs amputation in which case the game based on BCI interface is used as assistive technology. Also, for medical purposes the game proposed by us can be used by people with temporary medical problems mainly for the purpose of faster recovery, such as stroke, people who have suffered brain damage or for treating children that suffer from Attention-Deficit Hyperactivity Disorder (ADHD).

Based on simple user-driven mental commands, the game developed by us aims to improve the player's concentration power and level of attention by stimulating the brain to produce beta brainwave.

As a future development we propose: to adapt the game for mobile devices such as those running on the Android operating system as the Unity3D game development engine allows this, and commercial BCI systems now offer applications that provide the BCI interface for smartphones, smart devices especially for controlling other devices; to adapt the pool game in a manner that can be played in multiplayer mode by two player at the same time just like in the case of real pool game that should be in benefit of both player because the level of attention and concentration power increases when the two players are in direct competition to win the game; to export in cloud or save on computer the EEG data from gaming sessions for every player in part based on login data to be able to analyze them in offline mode using specialized software such as: BCI2000 that offers support for MatLab-Simulink development environment, EEGLAB a toolbox for MatLab or in Emotiv Xavier Test Bench, data that can be useful later in the medical field for diagnosis of brain disease or in patient recovery process.

#### References

- Anwar, S.M., Saeed, S.M.U., Majid, M., Usman, S., Mehmood, C.A., Liu, W., *A Game Player Expertise Level Classification System Using Electroencephalography (EEG)*, Appl. Sci., 8, 18, (2018).
- Bakaoukas, A.G., Coada, F., Liarokapis, F., *Examining brain activity while playing computer games*, Journal on Multimodal User Interfaces, 10.1: 13-29, (2016).
- Belkacem, A. N., Saetia, S., Zintus-art, K., Shin, D., Kambara, H., Yoshimura, N., Berrached, N. and Koike, Y., *Real-Time Control of a Video Game Using Eye Movements and Two Temporal EEG Sensors*, Computational Intelligence and Neuroscience, vol. 2015, Article ID 653639, 10 pages, <https://doi.org/10.1155/2015/653639>, (2015).
- Djamal, E.C., Abdullah, M.Y., Renaldi, F., *Brain Computer Interface Game Controlling Using Fast Fourier Transform and Learning Vector Quantization*, Journal of Telecommunication, Electronic and Computer Engineering (JTEC), 9.2-5: 71-74, (2017).
- Galway, L., McCullagh, P., Lightbody, G., Brennan, C. and Trainor, D., *The Potential of the Brain-Computer Interface for Learning: A Technology Review*, 2015 IEEE International Conference on Computer and Information Technology; Ubiquitous Computing and Communications; Dependable, Autonomic and Secure Computing; Pervasive Intelligence and Computing, Liverpool, pp. 1554-1559, doi: 10.1109/CIT/IUCC/DASC/PICOM.2015.234, (2015).

- Kerous, B., Skola, F., Liarokapis, F., *EEG-based BCI and video games: a progress report*. *Virtual Reality*, 22.2: 119-135, (2018).
- McMahan, T., Parberry, I., Parsons, T.D., *Modality specific assessment of video game player's experience using the Emotiv*, *Entertainment Computing*, 7: 1-6, (2015).
- Posen, E. S., *Is there Joy Beyond the Joystick?: Immersive Potential of Brain-Computer Interfaces*, (2018)
- Rosca, S.R., Leba, M., *Using brain-computer-interface for robot arm control*, In: *MATEC Web of Conferences*, EDP Sciences, p. 08006, (2017).
- Vasiljevic, G. A. M., De Miranda, L. C., De Menezes, B. C., *Mental War: An Attention-Based Single/Multiplayer Brain-Computer Interface Game*, In: *International Conference on Computational Science and Its Applications*, Springer, Cham, p. 450-465, (2018).
- Vourvopoulos, A., Niforatos, E., Hlinka, M., Škola, F. and Liarokapis, F., *Investigating the effect of user profile during training for BCI-based games*, 2017 9th International Conference on Virtual Worlds and Games for Serious Applications (VS-Games), Athens, pp. 117-124, doi: 10.1109/VS-GAMES.2017.8056579, (2017).
- Yang, B., Zhang, T., Duan, K., *Development of a BCI Simulated Application System Based on Unity3D*, In: 2015 International Conference on Virtual Reality and Visualization (ICVRV), IEEE, p. 277-280, (2015).

# Methodology for determining the replacement period for lifter bars

Teodora Hristova<sup>a</sup>

<sup>a</sup>*University of Mining and Geology “St. Ivan Rilski”, Sofia, BULGARIA*

---

## Abstract

The timely replacement of the drum mill liners brings about an increase in the quality of the milled product and reduces the milling costs. Therefore, an approach has been chosen to determine the replacement period for semi-autogenous mill liners in view of minimizing costs. A methodology has been developed to determine the service life of the milling lifter bars, whereby factors such as energy consumption, yield of the calculated class, productivity, price of liners, replacement costs and downtime loss are included. Costs are determined in terms of the type and quantity of the processed ore, balls, and backwater consumption that feed the mill. In the case under consideration, it has been found that it is economically most advantageous to replace the liners of the mill drum approximately every 4 months.

*Keywords:* lifter bar; liner; replacement period; energy cost;

---

## 1. Introduction

The individual components of the processing machines vary in terms of service lifetime. The faultless operation of machines and the extension of their service life is achieved through the timely replacement of the worn-out parts. These measures lead to a decrease in production costs but sometimes they result in a deteriorating production quality. In order to optimize production costs while maintaining the production quality, it is necessary to develop a methodology for determining the replacement period for some of the components that includes various factors, such as production safety, productivity, unit price, energy consumption, and others.

## 2. Subject of study

An object considered in the article is the mill liners which are changed in accordance with the wear of the lifter bars. This is a major component that yields a relatively large share in the formation of the production cost of the mineral processing plants.

## 3. Models to determine the duration of work of liners

In the case of mills, much of the decisions for capital replacement are taken in accordance with the engineering (Minin and Hainov, 2013 and Djordjevic, N. et al., 2004) and the economic safety requirements (Liao et al., 2006). In order to obtain higher economic benefits, deterministic economic models are recommended to use so as to determine the lifespan of the individual components of each machine (Kalala et al., 2008, Cleary, 2001, Yahyaei et al., 2009, Bearman and Briggs, 1998). These models are based on the depreciation term, on the estimate of the downtime costs, as well as on the consequences of failures and are applied by different authors. The disadvantage of the models described is the lack of information about the production quality, i.e. the reduction in particle size according to the wear of lifter bars.

Other researchers (Santarisi and Almomany, 2005) offer linear substitution strategies based on mathematical models of the wear of cement mill cladding. Their conclusions mainly concern the fact that the optimum replacement interval increases productivity (tons/hour) with reduced specific energy consumption and with a reduction in the price per unit of the cement produced.

\* Corresponding author. Tel.: +0-000-000-0000 ; fax: +0-000-000-0000 .

E-mail address: teodora@mgu.bg.

The review shows that it is necessary to develop a determinate model of liner replacement based on a broad perspective that includes the economic decision to influence maintenance in terms of quality and quantity of the mill production. For this purpose, it is necessary to perform an LCP (life cycle profit) or loss analysis based on the technological parameters. The maximum profits, the minimum losses, or maximizing the profitability of the mill can serve as criteria.

A model has been developed for maximizing gross profit (Dandotiya, 2011). However, profit depends not only on the technical parameters of production, but also on the market situation; therefore, this is not a suitable criteria for a longer period considered. The current research uses the model by Yun and Choi (Yun, Y.W, C.H. Choi, 2000), who suggest optimum replacement intervals in a repair system via the introduction of a random time horizon. They model a system according to a pre-determined period, wherein the optimum replacement interval is related to the minimizing of the expected costs. In this case, repairs are not carried out between two replacements. Also, their methodology does not include factors such as production efficiency, energy consumption, and metal recovery.

#### 4. Methodology for determining the period of lifter replacement

The present study offers the methodology and the subsequent data simulation that aim to minimize the life cycle cost by determining the optimum replacement interval. The life cycle model is based on a detailed analysis of the mill efficiency, the liner wear, and maintenance statistics. Practical data was used without taking into account the measurement of wear between two successive replacements.

##### 4.1. Output modeling data

##### 4.1.1. Factors influencing the model

The mathematical model is associated with determining the time for liner replacement and includes the following factors: product quality related to tons of ore produced; price for liner maintenance; ore density (the ratio of tons of balls, ore and water); and the amount of electricity consumed. For all these elements to be compatible, they are referred to the price per ton of ore produced. It has been established that the efficiency of the grinding process for each type of ore depends on the size of the lifter bars; therefore, in the model, their height is a basic parameter that leads to more efficient decision-making.

*Quality of the output product and percentage of metal recovery.* The quality of recovery decreases at a reduced size of the lifter bars because the mill revolutions are increased, the material is kept for a shorter period, and the pulp produced is with a larger grain size (Yahyaie et al., 2009, Schena et al., 1996). The purpose of determining the replacement period is to increase the percentage of metal extraction (recovery is achieved at a later stage - floatation), which leads to an increase in profitability and to lowering of price per unit produced.

*Changes in the mill volume due to wear.* In this case, the automatic control of the material feed rate is based on the instantaneous mill load. Liner wear leads to an increase of mill volume by up to 17%, which raises the throughput or capacity of the mill. As a result, the amount of the milled product is reduced.

*Variations in the energy consumption.* According to Djordjevic et al. (2004), Minin and Hainov, (2013) the relatively high lifter bars consume less power than outworn lifter bars under identical conditions (process parameters, such as: angular speed; mill filling with ore, water, balls; type of ore).

*Density of the ore (pulp).* According to the multivariate analysis, it is established that the most important parameter causing wear of lifter bars is the ore density (Wijaya, 2010). Ore density changes inversely with wear, which indicates to a directly proportional relationship between the density and life of the lifter bars.

*Maintenance of the liner.* Repair, inspection and accident downtime lead to high costs due to unproduced production.

The percentage of ore extraction is not included as a factor because it also depends on the floatation process.

Several assumptions are made in the techno-economic model to ensure that there are no variations in the life cycle due to changes in productivity levels. They are:

- 1) the total time with a lower level of pulp in mill is much shorter than the service life of the liner;
- 2) the wear of the liner itself is not measured as, in relation to the lifter bars, it is very insignificant in terms of percentage;
- 3) the wear of the liner was studied for a single kind of ore containing gold and copper;
- 4) the profile of the liner and the design of the lifter bars are not taken into account in the model.

##### 4.1.2. Model parameters.

This section briefly describes the parameters employed in the mathematical model.

*Suitability of the liners.* The technical suitability of the liner bars shall be tested throughout the lifetime at regular intervals. In this case, the data is taken on a daily basis.

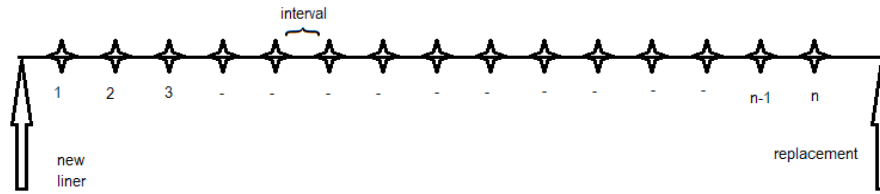


Fig.1. Measurement period

**Costs.** Costs are calculated for the entire exploitation period of the liner.

Total costs = [operating costs (energy costs) + replacement costs + costs for consumables], where

$$\sum_{i=1}^n E_i \cdot C_{energy} \quad (1)$$

where:  $E_i$  is the number of intervals,  $n$  is the duration of one cycle, and  $C_{energy}$  is the electricity costs [in BGN].

**Replacement costs.** Replacement costs of liners include the price of liners and the installation of a new inner liner, with each  $I^{th}$  interval being:

$$\frac{C_{rep}}{T_{cycle} + T_{rep}} t \quad (2)$$

where:  $T_{cycle}$  is the time for one cycle,  $T_{rep}$  is the repair time (interruption and replacement), and  $t$  is the duration of sampling intervals [measured in days],  $C_{rep}$  is the replacement cost.

In the case of an SAG mill, the cost of the liner is 37% of the total milling costs, see Catalog Manual (2002). Since interruptions happen only during repair operations, then in the case  $T_{cycle} = 0$ :

**Costs for consumables**, balls, etc. during the life cycle.

$$\sum_{i=1}^n E_i \cdot C_{cons} \quad (3)$$

where  $C_{cons}$  - is consumables per ton of ore [in BGN].

**Costs of stay.** The costs of stay or loss of production cannot be compensated and can lead to a breach of standard operations and to inefficiency. Downtime costs (or the so called production loss) are the most critical parameter in the decision-making model; i.e. the duration of the milling stops regardless of whether they are for liner inspection or replacement. Depending on the duration of the shutdown, the energy costs and the production efficiency costs vary, too. Therefore, in the particular case, the cost per hour is assumed to be constant for each cycle of time, with the downtime cost for each  $I^{th}$  sampling interval being as follows:

$$\frac{C_{DR}}{T_{cycle} + T_{rep}} t \quad (4)$$

where  $C_{DR}$  - is the stay costs [in BGN].

In the model, it is assumed that downtime losses for the planning horizon are reduced to the price of unprocessed gold and copper:

$$C_{DR} = (T_{rep} \cdot C_{Cu} + T_{rep} \cdot C_{Au}) \frac{T_{max}}{T_{cycle} + T_{rep}} = (T_{rep} \cdot Q_r \cdot I_z \cdot C_{Cu1} + T_{rep} \cdot Q_r \cdot I_z \cdot C_{Au1}) \frac{T_{max}}{T_{cycle} + T_{rep}} \quad (5)$$

where  $T_{max}$  is the maximum time for 10 years which is equal to the days of work and stay;  $C_{Cu1}$  and  $C_{Au1}$  are the prices of copper and gold per kilogram;  $I_z$  is the percentage of gold or copper content in the ore;  $Q_r$  is the amount of ore per day.

As production losses, liner prices, metal prices on the stock exchange, etc. may vary over the years, to reduce the prediction error for a longer period of time, the expression is simplified and reduced to a loss minimization model:

$$C = \sum_{i=1}^n E_i \cdot C_{energy} + \sum_{i=1}^n E_i \cdot C_{cons} + \frac{C_{rep}}{T_{cycle} + T_{rep}} t + \frac{C_{DR}}{T_{cycle} + T_{rep}} t \quad (6)$$

The optimization approach is based on a comparison of gross costs at different replacement intervals.

To justify the model, the horizon concept is introduced for a planned period (days, months): The lifetime of the liner from its installation to its removal. This is employed to calculate the LCC. The optimization used in this case is based on two scenarios L (long) and S (short) with a data interval for one liner cycle. The S scenario contains fewer days  $T_s$ , whereas the L scenario contains more days  $T_l$ ; consequently  $T_l > T_s$ . A longer time  $T_{max}$ , including time is selected that comprises several L or S scenarios.

The comparison is performed over a given time horizon of  $T_{max}$  in order to determine the best interval for loss minimization.  $T_{max}$  is at the threshold of the lifespan of the liners and includes the installation time and the operation time. To determine the number of cycles  $N$ , the dependence is used:

$$N = \frac{T_{max}}{T_{cycle} + T_{rep}} \quad (7)$$

where  $T_{max}$  is the maximum study period;  $T_{cycle}$  is the mill operation time;  $T_{rep}$  is the shutdown time for liner replacement.

In order to optimize the life cycle, as well as to reduce the cost of staying, it is advisable to make a diagram of cost minimizing, including downtime loss, per production unit. For this purpose, time intervals have been introduced for a period of 10 years or 120 months, both of which are close to the L scenario. The L interval is assumed to be 150 days and the S interval is 135 days. To compare two L and S scenarios, the gross loss is calculated for  $T_{max}$  days.

## Results

For the verification of the techno-economic model, data was obtained from a semi-autogenous mill for processing ore with gold and copper content, but due to the confidentiality of the data used those have been scaled. Based on these, models were developed to determine the correlation between the liner wear and the process parameters for the entire lifetime of the liners. Through variations in the liner life cycle over a longer period of time, a decision was made related to the optimum replacement period.

All costs per ton of ore produced are visualized by the graphs in Fig. 2 with their variation in days within a period of 150 days, of which 147 days are the operation of the mill and 3 are for the liner replacement. In the graph,  $R_b$  are the costs of balls,  $R$  are the total costs (including water),  $R_{liner}$  are liner costs, and  $R_e$  are the electricity costs.

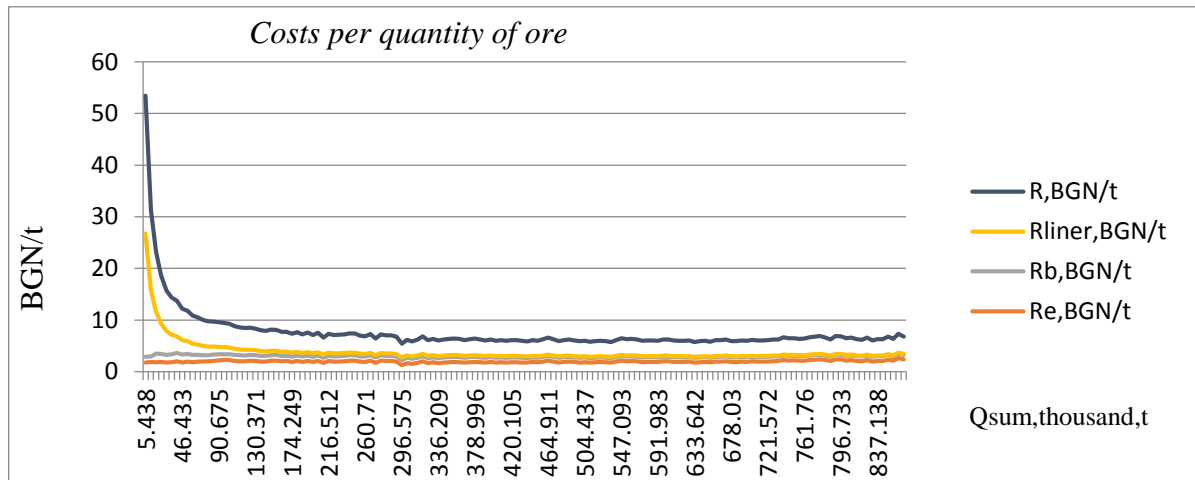


Fig. 2. Costs versus amount of ore

It is clear from the graph that for the amount of ore of 128,439 thousand tons the price of liner becomes lower than the price of electricity per ton of ore. At the end of the period, the energy cost and total cost increase. It is economically more profitable to replace the liner before the cost rises. Fig. 3a) shows these costs and for better visibility Fig.3.b) gives the costs for the end of the period.

The graph shows that the costs that are on the increase are those for electricity and the total costs. For the sake of clarity, they are outlined against the entire period of liner operation.

The calculations show that costs are on the rise after 120 days. To clarify the moment to replacement, the optimization approach is applied. For this, we assume that  $T_{max} = 120$  months, and we choose the horizon periods: 150 days for the first variant and 135 days for the second variant. It is estimated that  $120/5 = 24$  liners are replaced within 10 years in the first variant. The second variant is two weeks shorter and the number of liners replaced within the same period will be 26.6. Costs are calculated after the dependence (6) or for variant one - BGN 13383,0864 thousand over a period of 10 years, with the duration of liner operation of nearly 5 months. For a period of operation of 4.5 months, the amount is BGN 12254,4033 thousand.

For the entire period of operation, the  $T_{max}$  costs are calculated on the basis of the following dependence:

$$C_{zag} = \left( \sum_{i=1}^n E_i \cdot C_{energy} + \sum_{i=1}^n E_i \cdot C_{cons} + C_{rep} + C_{DR} \right) \frac{T_{max}}{T_{cycle} + T_{rep}} = \left( \sum_{i=1}^n E_i \cdot C_{energy} + \sum_{i=1}^n E_i \cdot C_{cons} + C_{rep} + C_{Cu} + C_{Au} \right) N \quad (8)$$



The variation in gross cost is determined by a simulation program for ( $n = 1, 2, 3 \dots$  Trisk), where Trisk represents the maximum number of days in operation of the liners before their thickness is reduced to the hazardous zone, i.e. one which implies a risk of damaging the mill. Also, the discounted rate is not taken into account due to the short technical life cycle of the liner as compared to the lifespan of the whole mill.

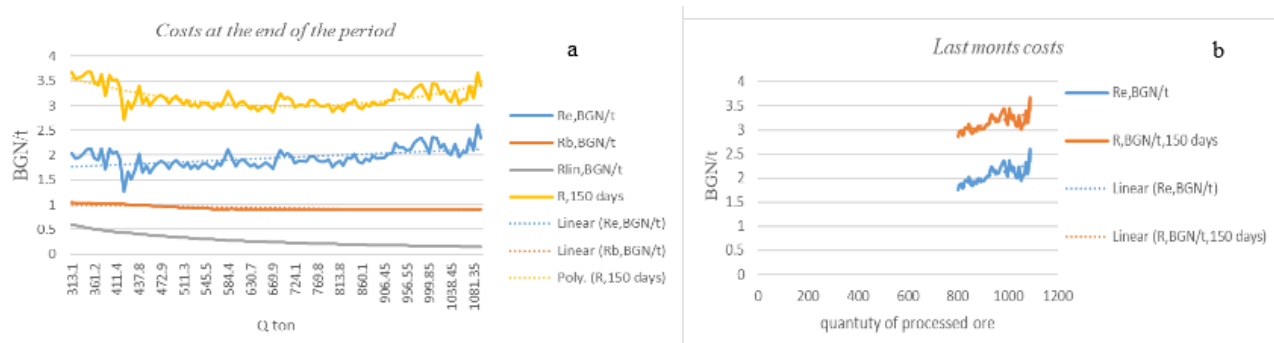


Fig. 3a). Costs for the last month and 3b) Total costs and electricity costs at the end of the period

The cumulative cost curve for a horizon of 150 days looks like this (Figure 4). It is obvious that the minimum is approximately on day 120 and it is economically more profitable to replace the liner during this period. At minimum costs for variants of 2 to 150 days, the last days of the cycle are shown in Fig. 5.

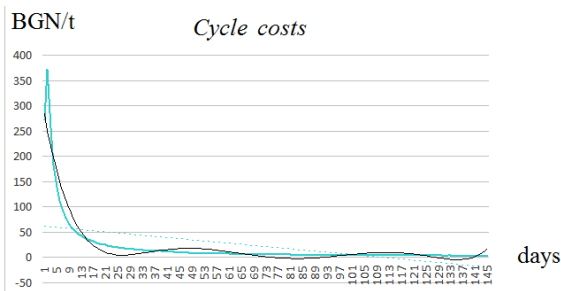


Fig. 4. Cost curve for a 150-day period

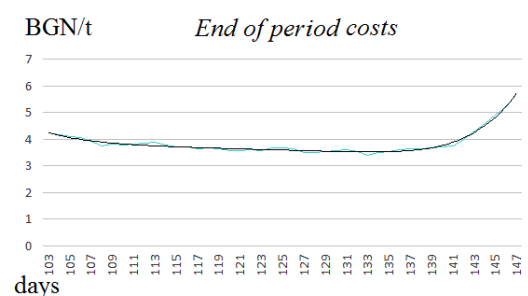


Fig. 5. Total costs to end of the period for the first variant of a 150-day cycle

With 120-month planning  $T_{max}$ , which is consistent with the proposed Optimization Maintenance Policy, the results of this study show (see Fig. 5) that around day 141, the cost curve reaches a minimum, and then rises. This indicates that it is appropriate to replace the liner after 138 days or after 8,000,000 tons of processed ore. If a 10% error is included due to the replacement of the type of liner, or to ore characteristics, or to the change in the price of metals on the exchange, etc., then it is normal to change the liner after 140 days. Despite the long horizon, the sensitivity of the model results ranges from 1-2% for the various optimum scenarios.

Fig. 6 compares to two variants with cycles of 150 and 120 days, respectively. There are shown two L and S scenarios with the corresponding curves. The total area of the loss curves in the S scenario is less than the total area of the curves in the L scenario. This is due to better process efficiency and to the lower power consumption in the initial phases of the life cycle of the liner bars. At the same time, the S scenario has more substitute times than the L scenario, which leads to more downtime costs, but despite everything, the total costs over a 10-year period remain lower. Therefore, the life cycle is optimised based on the minimisation of the loss curve for a given time horizon.

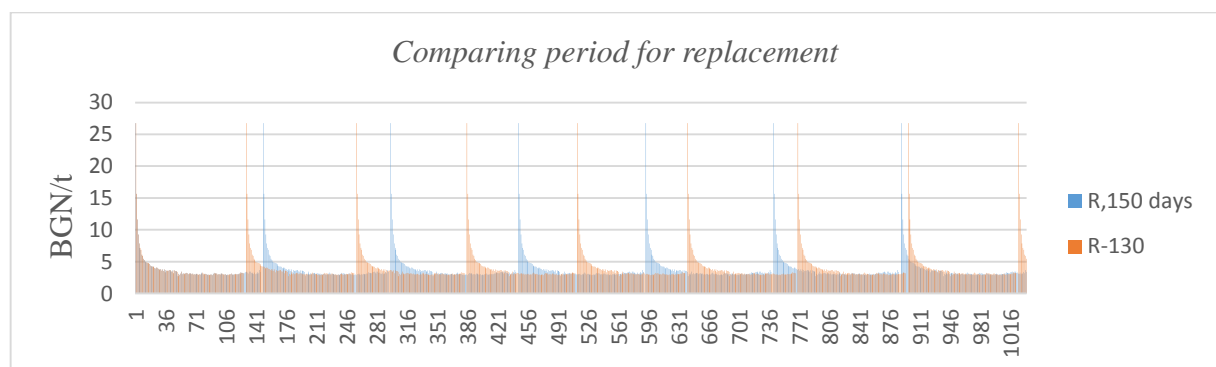


Fig. 6. Location of the cycles for both variants

## Conclusion

In conclusion, the following inferences can be drawn:

1. The timely replacement of lifter bars will not only reduce the costs per ton of ore but will increase the quality of the milled product.
2. By economic criteria, this should be done earlier, around day 136 or, in this case, after 800,000 tons of processed ore with these liner bars.
3. For greater precision of measurements, it is necessary to monitor the liner wear with a laser scanner that also measures the shape of the lifter bars at least twice a month.
4. When replacing the liner manufacturer or the liner configuration, the study hereby should be repeated.
5. The results of this study are valid for the type of processed ore during the specified period.

When establishing the boundary wear by economic criteria, all metal, electricity, and liner prices used in the model, along with the liner replacement, were determined at the beginning of 2015.

## References

- Bearman, R.A. and Briggs, C.A. (1998), *The active use of crushers to control product requirements*, Minerals Engineering, Vol. 11, No.9, pp. 849–859.
- Dandotiya, R. and Lundberg, J. (2011), *Replacement decision model for mill liners*, Journal of Quality in Maintenance Engineering (Accepted)
- Djordjevic, N., Shi, F.N. and Morrison, R. (2004), *Determination of lifter design, speed and filling effects in AG mills by 3D DEM.*, Minerals Engineering, Vol. 17, No.11–12, pp. 1135–1142.
- Kalala, J.T., Breetzke, M. and Moys, M.H. (2008), *Study of the influence of liner wear on the load behaviour of an industrial dry tumbling mill using the Discrete Element Method (DEM)*, International Journal of Mineral Processing, Vol. 86, No. 1–4, pp. 33–39.
- Liao, H., Elsayed, E.A. and Chan, L.Y. (2006), *Maintenance of continuously monitored degrading systems*, European Journal of Operational Research, Vol. 175, No. 2, pp.821–835.
- Minin I., Hainov L., *Establishment of a mathematical model of grinding process in sag mill to examine the relative energy consumption in industrial conditions*, XV Balkan Mineral Processing Congress, Sozopol, 2013, vol. 1, p.199.
- Santarisi, N.S. and Almomany, R.M. (2005), *Mathematical modelling of wear rate of non-repairable parts and their replacement strategies: cement mill liners as a case study*, Journal of Quality in Maintenance Engineering, Vol. 11, No.1, pp. 68–81.
- Schena, G., Casali, A. and Vallebuona, G. (1996), *Optimal throughput policies for a copper concentrator*, Minerals Engineering, Vol. 9, No. 11, pp.1105–1117.
- Yahyaee, M., Banisi S. and Hadizadeh, M. (2009), *Modification of SAG mill liner shape based on 3-D liner wear profile measurements*, International Journal of Mineral Processing, Vol. 91, No.3–4, pp.111–115.
- Yun, Y.W. and Choi, C.H. (2000), *Optimum replacement intervals with random time horizon*, Journal of Quality in Maintenance Engineering, Vol. 6, No. 4, pp. 269–274.
- Wijaya, 2010 Wijaya, A. R. (2010), *Multivariate analysis to predict the lifetime of liner due to wear*, An internal report, Lulea University of technology, Sweden.

## Increasing quality through the study of the use of extraction complexes using modern methods of mathematical statistics

Marin Silviu Nan<sup>a</sup>, Danuț Grecea<sup>b\*</sup>, Stela Dinescu<sup>a</sup>, Andreea Ungur<sup>a</sup>, Alin Sultan<sup>a</sup>

<sup>a</sup> University of Petrosani, 20 University street, 332006, Petrosani, Romania

<sup>b</sup> National Institute for Research and Development in Mine Safety and Protection to Explosion - INSEMEX, 32-34 G-ral Vasile Milea Street, Petrosani, ROMANIA

---

### Abstract

The paper addresses the problem of determining the coefficients of use over time to the theoretical level and at the level applied in reference to extraction complexes used in open-pit lignite exploitation. In this sense, for the first time in our country we achieved a mathematical statistical analysis of how the elements of the system for extracting from a database by means of empirical processed malfunctions of the highest topical. There were significant correlations between obtained a set of parameters that influence the performance of the operation. Conclusions were useful to split off significant elements affecting the time coefficients respectively capacitive indicators.

*Keywords:* statistics, mathematical methods, reliability, maintenance

---

### 1. General conditions

The problem of determining the coefficients of use over time to the theoretical level and at the level applied in reference to extraction complexes used in open-pit lignite exploitation is extremely important. That is why the process must work efficiently, which means that it must be reliable and on the other hand it must have the highest excavation capacity at specific energy consumption as low possible.

Increasing efficiency in work is subject of choice in accordance with actual operating conditions and all equipment on extraction technological lines of lignite and sterile from the roof of lignite layers to be in correlation. It should also be ensured reasonable exploitation in terms of intensive and extensive, and the adoption of a modern and efficient system for carrying out maintenance, being necessary the rehabilitation processes completion and modernization in order to maintain the level of their technical status.

The entire scope of paper considers the extraction complexes used in Oltenia open-pit coal field, especially Jilt Mining. Such theoretical aspects are tackled classic which allows qualitative and quantitative appreciation of the use of in time for excavation, transport and storage equipment of the extraction system.

Is analysed the evolution of usability for equipment on the technological lines. To do this, it is uses well-organized database of operation time for equipment from extracting complex machinery. Using the mathematical statistics methods was conducted a detailed analysis of influence for each parameter on use over time an extraction system.

---

\* Danuț Grecea. Tel.: +40723809482; fax: +40254546277  
E-mail address: greceadanu@gmail.com.

## 2. Theoretical issues concerning the study of the use of machinery, excavation, transport and storage

The study of use time and capacity of technological systems with complex configuration is an issue of great importance and involves levels and different "angles" approach. This study allows for quantification of intensive and extensively uses, both at the level of each component, as well as at the level of the system as a whole. Applying this methodology presupposes the existence of a database "radiography" item or operation studied system. The downside of this methodology derives from the fact that captures quantitative aspects, but the use of another method based on statistical analysis and calculation software gentle this impediment.

This new approach represents an effective means for studying the functioning of extracting technological systems but the full resolution this presupposes the existence of a monitoring system and a database that will provide the knowledge real time operation the technological capacity of the system.

The efficiency of the use of equipment for excavation, transport and dumping within the exploitation of lignite is synthesized through three indicators. They are determined by collecting and processing statistical data relating to operating and stationary times, for machinery from technological flow. With the help of these operating and stationary times use indices are calculated:

- extensive use coefficient;
- intensive use coefficient;
- global use coefficient.

Extensive use coefficient,  $I_E$ , is an indicator that is calculated on the basis of the operation hours reported of calendar time:

$$I_E = \frac{t_f}{t_c} \quad (1)$$

where:  $t_f$  – represent operating time,  $h$  and  $t_c$  – is calendar time,  $h$ .

Intensive use coefficient is given by the relationship:

$$I_i = \frac{Q_R}{Q_T} \quad (2)$$

where:  $Q_R$  – made hourly capacity,  $m^3/h$  or  $t/h$  și  $Q_T$  – theoretical hourly capacity,  $m^3/h$  or  $t/h$ .

Made hourly capacity represents the ratio of the excavated mass (sterile and/or coal) and operating time:

$$Q_R = \frac{M_E}{t_f}, [m^3/h] \text{ or } [t/h] \quad (3)$$

where:  $M_E$  – excavated mass,  $m^3$  or  $t$

Global use coefficient ( $I_G$ ) is calculated by multiplying the extensive use coefficient whit intensive use coefficient:

$$I_G = I_I \cdot I_E \quad (4)$$

## 3. Research on the evolution over time of use for equipment from technological lines

The use degree of technological machinery may be expressed by determining the coefficients of extensive use, intensive use and global. Based on the recorded data and considering the time period 2001 ... 2015, histograms were constructed on the utilization degree. Thus is shown in Figure 1, the histogram for the coefficient of use extensively, intensively and histogram for global use coefficient, all for the Jilt Mining.

It is noted that extensive use coefficient has a general trend of increase in the period under review. Thus in the year 2001 the value of this indicator was 0.16, in the year 2015 has reached the value of 0.40. There is some time between the years 2007 and 2010 found a slight decrease. Intensive use coefficient has a slightly increasing trend to rise 0.29 in the year 2001, the amount of 0.41 in the year 2013. In the year 2015 this coefficient reaches the value of 0.36.

Global use coefficient has a general trend of increase in the amount of 0.05 in the year 2001 and the value of 0.15 in the year 2015.

The growth use coefficients are explained by the completion of some phases of restructuring and modernization, and this increase is due to mentality changes and thanks to the new realities of the market economy.

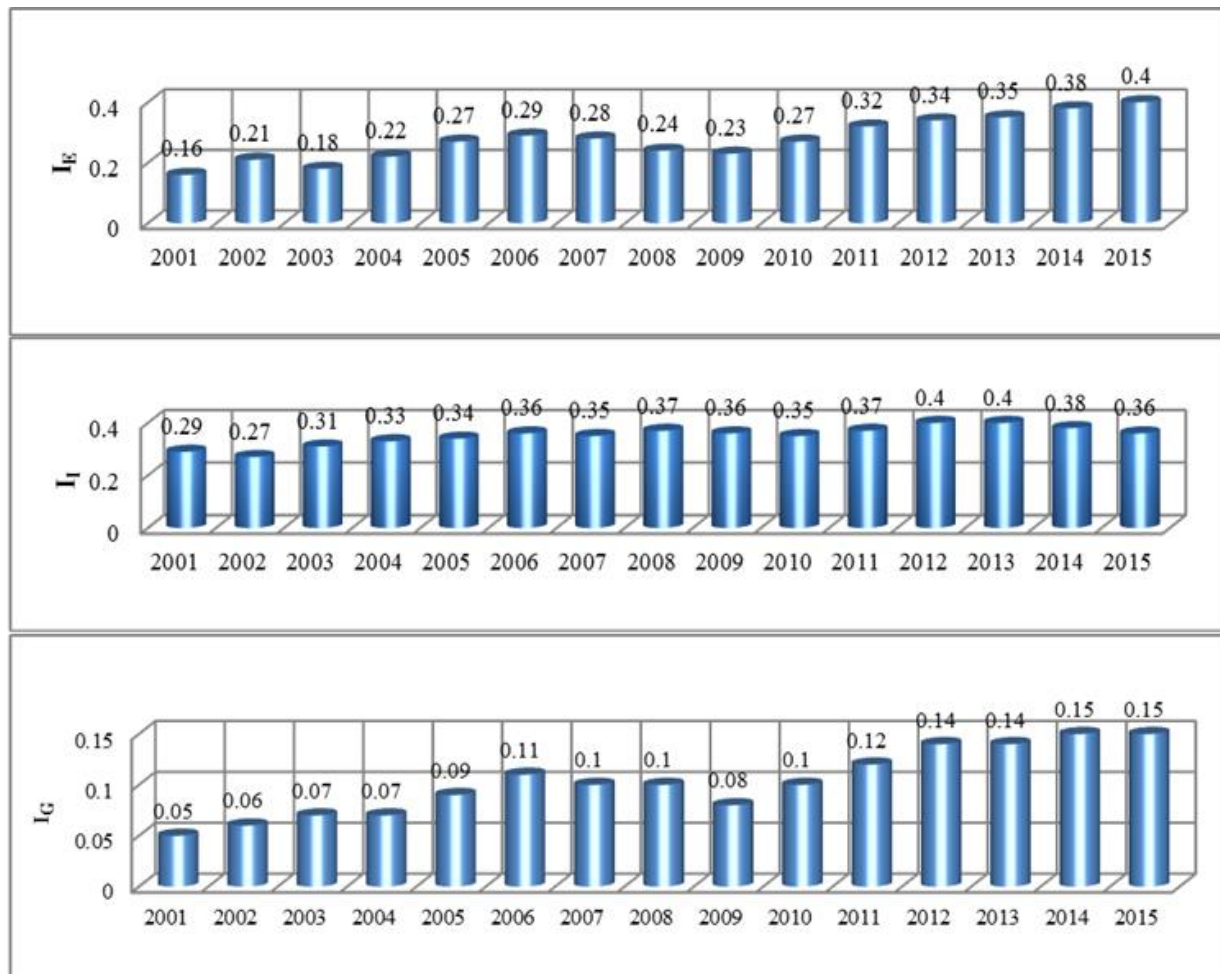


Fig. 1. The evolution over time of the extensive, intensive and global use coefficient for the Open-Pit Jilț Mining

#### 4. The study of utilization in time a extraction complexes using mathematics statistical methods

Calculation methods for determining the capacity of extracting systems differ and depending on the system type. In the present paper considering only continuously extraction systems, in this sense, we consider their use over time, respectively theirs real production capacity.

There are problems of great difficulty, derived from the complexity of system, the number of influence parameters their time variation, geological conditions and geographical conditions. Other factors of influence are weather conditions, social aspects, energy market, etc.

For determination of extraction capacity, transport and storage it must be calculated from to beginning for a longer period (month, year), this objective involves defining of transported volume determined by every extracting element in part. The production capacity of the system is the sum of production capacity of extracting elements.

The paper approaches operating time evaluation of extraction system and their use coefficient in time. By this magnitude the behaviour of the system is manifested, respectively the mutual interaction between its elements. Using SPSS - SELF - SERVICE DATA ANALYTICS software, a detailed statistical study has been developed that takes into account dependent and independent variables that define, from a perspective use time, the components of the complex extraction system.

Normality tests were performed, mathematical fireworks were applied in less informative areas, and multiple regression methods were developed for statistical motivation of dependent variables versus independent variables, and useful correlations were established between these.

It follows that from a capacitive point of view the system is influenced by the actual operating time of the extraction elements. In turn, the running time determines value of the working time and the planned stop times, and the sum of the working time and stop time is the calendar time.

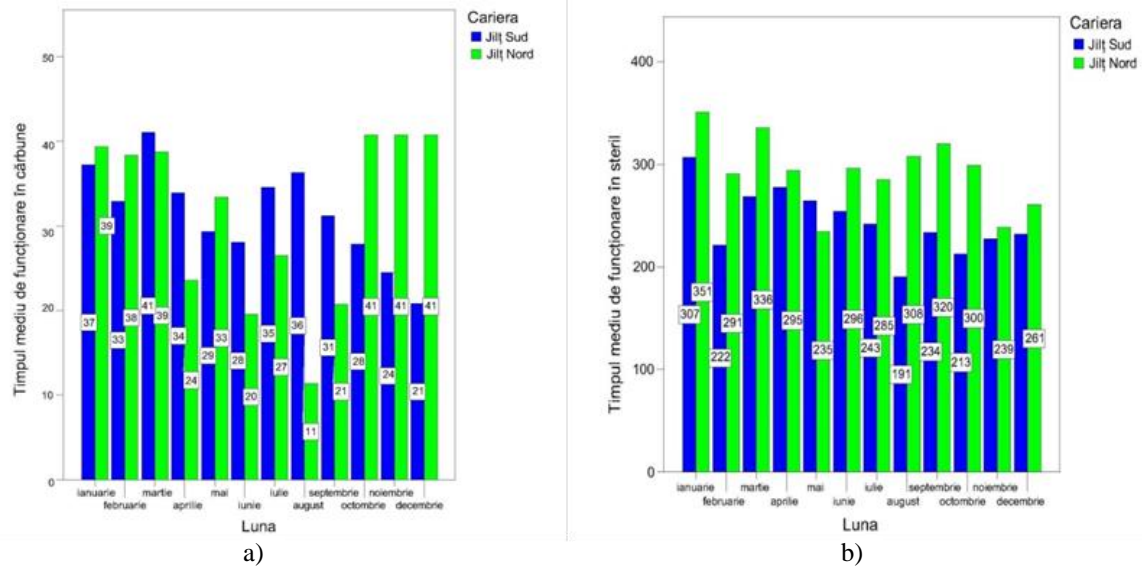


Fig. 2. The average operating time chart a) in coal; b) in sterile

We will approach from the point of view of statistical data resulting from monitoring over time of the extraction system in the year 2011 Open-Pit Jilt Mining. It was chosen this year as the basis of a careful analysis it was observed for this period, the relative dates are complete and well structured.

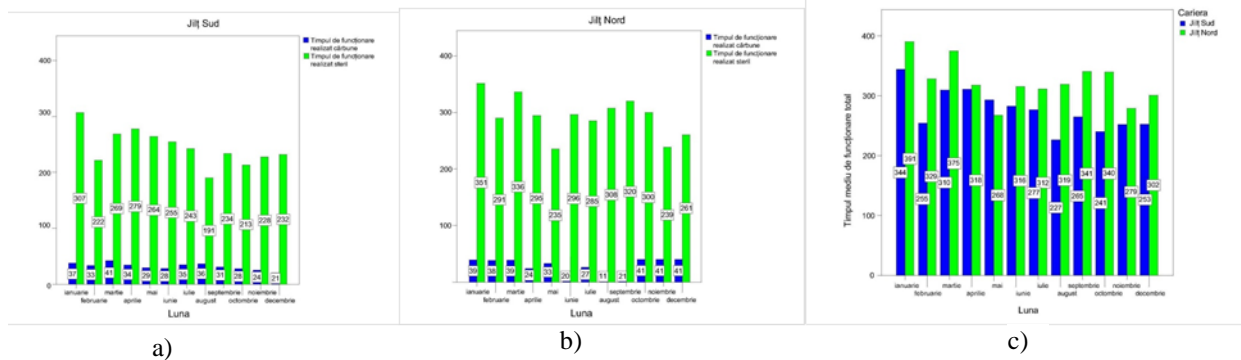


Fig. 3. The operating time chart in open-pit mining a) Jilt South; b) Jilt North and c) total

Based on these data have been presented graphically and analysed the main elements of influence in the use of extraction systems.

In Figure 2, it is observed that during the operation of the extraction system in the coal has a fairly large variation. It is a minimum of 10 hours per month in the Jilt North open-pit mining and 42 hours per month in the Jilt South open-pit mining. Consistency in operation occurs in the Jilt North, where in 3 consecutive months (October, November and December) operating time is 40 hours.

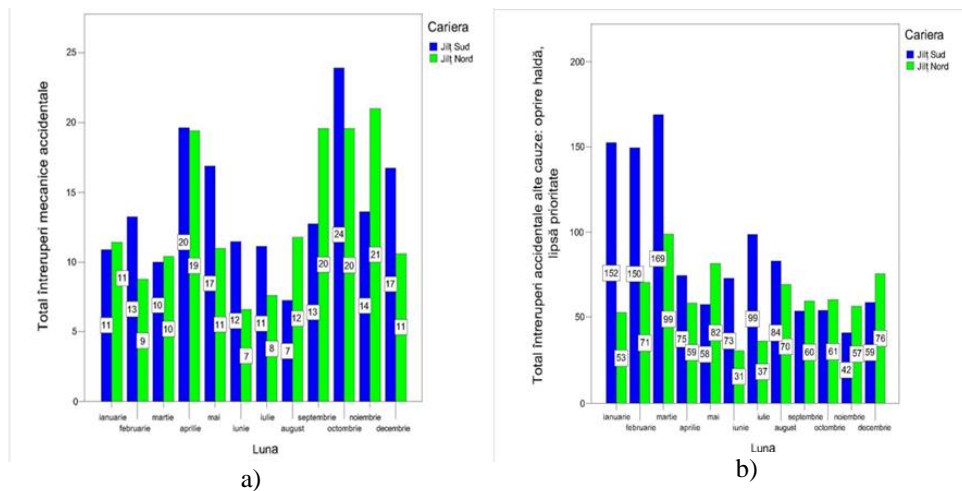


Fig. 4. Interruption times chart a) accidental mechanical; b) other accidental causes

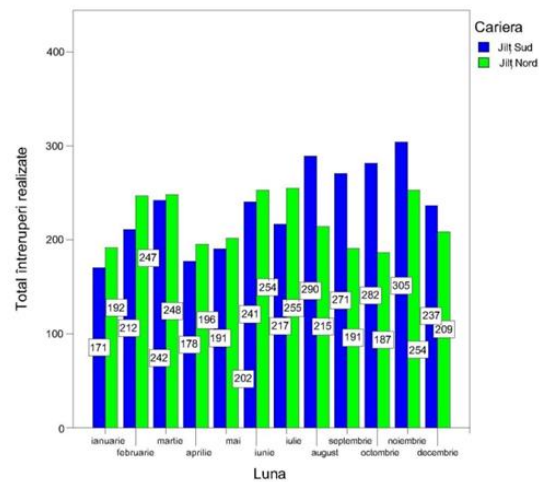


Fig. 5. Realized interrupt chart

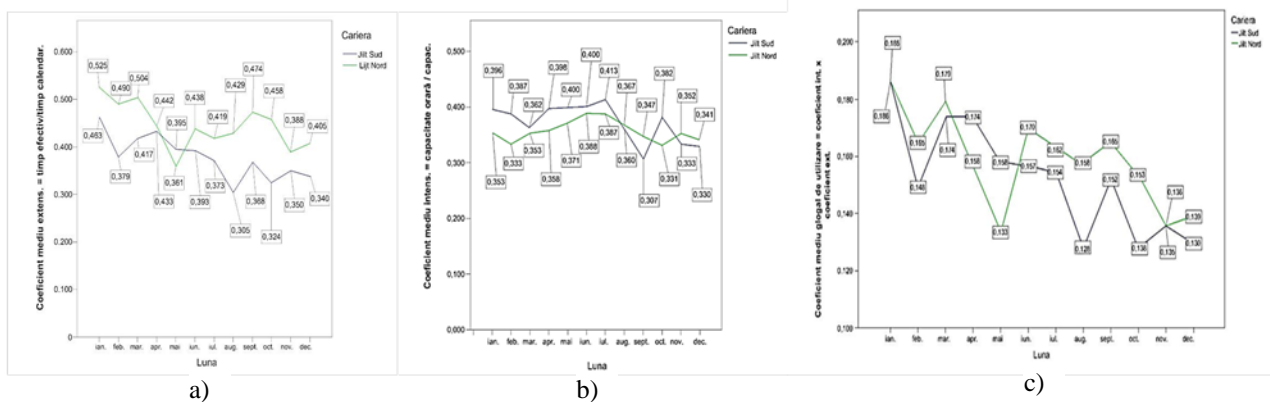


Fig. 6. a) The extensive use average coefficient chart; b) The intensive use average coefficient chart; c) The global use average coefficient chart.

## 5. Conclusion

From this approach we can see that there are important reserves for increasing use of extraction systems over time, so effort of knowledge will focus on scientific discovery of causes and measures to be taken to improve situation, thereby increasing production capacity will reduce costs, and lignite extraction will become more and more competitive.

This approach allows a profound understanding over time functioning of the extraction system components through the mutual influence light.

A fairly complex picture is provided, which implies a certain level of readiness, but can lead to well-grounded decisions, decisions must be followed by actions leading to an increase in use of the system subject to analysis.

The adoption of modern maintenance systems and modernization processes completion ensures increased lifetime for extraction system from open-pit Jilt Mining, even though some are approaching the maximum exploitation time and others have exceeded this limit. Adoption of this strategy is valid because it and other countries with developed mining industry was extended the life of the equipment of high complexity (as bucket wheel excavator) by monitoring the operation, data processing and modernization measures aimed at ensuring the success of the approach to be used in the operation of such equipment.

## References

- Bogdan, C., Nan, M.S., Grecea, D., Mamară, N.L. *Comparison of constrained optimization functions*; 17th International Multidisciplinary Scientific GeoConference SGEM 2017, Conference Proceedings, ISBN 978-619-7408-01-0/ISSN 1314-2704, Vol. 17, Issue 21, 217-222 pp, DOI: 10.5593/sgem2017/21/S07.028, (2017)
- Bogdan, C., Nan, M.S., Mamara, N.L., Grecea, D. *Numerical nonlinear global optimization*; 17th International Multidisciplinary Scientific GeoConference SGEM 2017, Conference Proceedings, ISBN 978-619-7408-01-0/ISSN 1314-2704, Vol. 17, Issue 21, 479-484 pp, DOI: 10.5593/sgem2017/21/S07.061, 2017
- Florea, C., Florea, A., Dunca, F. - *Restorability Possibilities of the Tehnological Equipment By Using Composite Materials*, International Scientific Practical Conference Micro Cad, Harkov, 17-18 Mai (2007)



- Nan, M.S., Jula, D. – *Capacitatea sistemelor de transport*. Editura Universitas, Petroșani, (2000)
- Nan, M.S., Bogdan, C., Grecea, D., Mamară, N.L. *Exact global optimization*; 17th International Multidisciplinary Scientific GeoConference SGEM 2017, Conference Proceedings, ISBN 978-619-7408-01-0 /ISSN 1314-2704, Vol. 17, Issue 21, 303-310 pp, DOI: 10.5593/sgem2017/21/S07.039, (2017)
- Nan, M.S, Grecea, D., Nicola, A.H. – *Metodologia cercetării științifice* , Editura Universitas, Petroșani, ISBN 978-973-741-484-7, 300 pag, (2016)
- Nan, M.S, *Parametrii procesului de excavare la excavatoarele cu rotor*, Editura Universitas, Petrosani, (2007)
- Nan, S. M., Iacob – Ridzi, F. T., Dandea, D. L. - *Teoria sistemelor de transport*, Editura UNIVERSITAS, Petroșani, (2012)
- Ungureanu, N. S. - *Fiabilitate și diagnoză*. Editura RISOPRINT Cluj-Napoca, (2003)

## Development of a cutting and hauling device for limestone dimension stone mines

Zoltán Virág<sup>a\*</sup>, Viktor Fülöp<sup>b</sup>, József Molnár<sup>a</sup>

<sup>a</sup> Institute of Mining and Geotechnical Engineering, University of Miskolc, Egyetemváros, H-3515 Miskolc, Hungary

<sup>b</sup> Institute of Forestry Economics and Rural Development, University of Sopron, Bajcsy-Zsilinszky u. 4., H-9400 Sopron, Hungary

---

### Abstract

The aim of the research is to optimize the production of small volume dimension stone products – mainly in limestone quarries - with the re-thinking of the use of production and transport equipment. The tool to be developed for both production and transport can reduce the number of mining machines to be used in the mine. It is planned to reduce the expenses of running mining businesses, which include mining operations, costs of maintenance. This paper shows the initial steps to develop a dimension stone mining adapter for a Construction Loadall base machine.

*Keywords:* prototype, development, mining, limestone, adapter

---

### 1. Introduction

The Institute of Mining and Geotechnical Engineering of University of Miskolc started the development of a small volume mining production and transport adapter suitable for limestone in the MIOCÉN project with the project managements of FÉMGER Kft. and HOBAGÉP Bt.

The aim of the research is to optimize the production of small volume dimension stone products – mainly in limestone quarries - with the re-thinking of the use of production and transport equipment. The tool to be developed for both production and transport can reduce the number of mining machines to be used in the mine. It is planned to reduce the expenses of running mining businesses, which include mining operations, costs of maintenance. The goal is to be cheaper on the market and to be more competitive with the companies in the market (Fülöp et al., 2017).

### 2. Limestone Leitha

For the design of the adapter to be developed and the selected technology, the determination of the mined rock environment was essential. The rock selected from the point of view of the project is the limestone Leitha in the Sopron Mountains, which is the main component of this area. The name of the stone was derived from the Leitha Mountain (or river), which separates the former Hungary from Austria.

Limestone in Fertőrákos and in Margitbánya (located in Austria) has been a popular building material for millennia: the Celts and the Romans living there used this stone as well. The nearby Carnuntum (near today Vienna) and the buildings and the protective walls of Scarbantia (Sopron) are made of this material.

From the 18th century it became a popular building material. They were easy to mine and transport, massive amounts of blocks were transported to the buildings of nearby big cities. Much of the houses in Vienna and Bratislava were made of this material, but in almost every village around Sopron we find buildings built from "Rákosi" stone. At first only the temples were built out of it (e.g. the Saint Michael church in Sopron, Stephansdom in Vienna), but soon it was the basic material of the residential buildings. We could mention the Esterhazy Castle in Fertőd (Fig. 1.) or the Castle of Festetics in Keszthely. In addition to the building work, it also served as a base for many tombs, memorials and sculptures.

---

\* Corresponding author. Tel.: +36-46-565-111/18-08  
E-mail address: gtbvir@uni-miskolc.hu



Fig. 1. Esterházy Castle in Fertőd (Wikipedia)

Rákosi stone is moderately resistant to weather, so it is best to use in plaster finished structures. The example of the Trinity of Kőszeg has been a good example of the relatively poor resistance, which was set up in 1713, but since it has been restored 3 times (1813, 1869 and 1974). The pedestals of the Buda Castle buildings were made of this stone (the stones which were recently removed from Margitbánya, unfortunately they are also destroyed by the salting of roads and pavements). These future reconstruction needs have justified our choice of cooperation with “Fertőrákosi II” limestone quarry.

The Rákosi limestone is 100 - 150 m thick, large-grained shallow-sea sediment. Its material is made up of reddish algae, snails, shells, sea-urchins and bryozoas. The color of the rock is yellowish-white. Its density is between 1750 kg/m<sup>3</sup> and 2500 kg/m<sup>3</sup> in the air-dry state. Its compressive strength is typically around 10 MPa. (Mednyánszky, 2017, Török, 2008).

### 3. Methods of production of dimensional stones

To develop the rock winning technology, it is imperative to know the geological knowledge of the site and the use of the extracted material. Based on these, we must choose which way to start optimally in the development.

There are several versions of the dimensional stone production, which are:

- a) Block production with a large borehole blasting technology, in which we create oversize blocks, which require further cutting or shaping.
- b) Cleavage of stone blocks using chemical swelling energy. One way is to use water-swellable mixtures for rock fracturing purposes.
- c) Use of mechanical, hydraulic and combined rock setting wedges placed in small-diameter holes. Hydraulic units consist of a high-pressure hydraulic unit and a tensioning tool. Owing to the high-pressure hydraulic unit the wedge tensioning tools cause tension to the walls of the holes, thereby developing tensile stresses in the stones between the holes.
- d) Creating blocks by drilling when the boreholes are drilled densely along the contour of the block so that they are in contact or interconnected.
- e) Rock sawing, which can be done with disc, chain and rope. The gentlest block production method is the sawing of blocks. For the smooth operation of the rock saws it is necessary that the rock is free from cracks.



Fig. 2. An abandoned building stone mine (Molnár, 2012)

To mining blocks in a place where blocks are not sawed, a large number of boreholes are needed. The boreholes have to be spaced from 15 to 40 cm apart to allow the rock to be fractured along a certain plane.

Since the most gentle production method is rock sawing, and to reduce the number of machines, we plan to solve the production with a design that is capable of winning and transport.

#### **4. The prototype adapter**

The basic machine for the adapter is provided by a JCB Construction Loadall (Fig. 3.). Due to the large load capacity and design of the machine, it is used for different workflows in many areas. Its multifunctional applicability ensures that the hydraulic system of the requested machine has a pump capacity of 140 l/min and a working pressure of 260 bar.



Fig. 3. The basic machine of the project, a JCB Construction Loadall

Based on the new technology, the adapter can be disassembled into two main units. One of them is the cutting chain saw unit combined with a feed and rotation hydraulic system and a hydraulic rotary unit. This part of the adapter can cut from three sides perpendicular to the front face.

The structure of the rock chain saw contains individually manufactured elements, such as chain-shaped teeth, which are formed in a specific, unique order on the chain and form 7-8 teeth-repeating chains, specially developed for rock quality (Fig. 4.). The shape of the cutting device is very important because of the cutting forces and loads (Tomus, O. B., Rada, A. C., 2017). High loads can produce unwanted effects on mining system (Andras et al., 2016). During design the chain guide should be designed separately, which should consider the lubrication system to be used to reduce friction during operation.

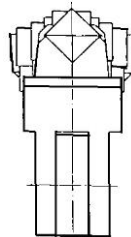


Fig. 4. Special chain saw elements (front-wise)

The other main machine unit serves to support and move the first main unit while cutting and performs stability and elevation of the block with an object table, which is subject to heavy wear and tear during the mining use.

Testing the prototype adapter (Fig. 5.) is unavoidable during the development period, which will be carried out at the manufacturing workshop and in the limestone quarry. During testing, the static and dynamic uses of the units in the adapter are studied, even in extreme cases, to determine the more accurate technical parameters.

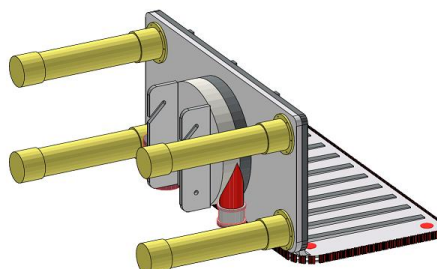


Fig. 5. An initial version of the prototype adapter

## 5. Conclusion

Future reconstructions of historic buildings, tombs, memorials and sculptures need good quality dimensional limestones. This is why we start a new project to design a mining adapter. To develop the rock winning technology, it is imperative to know the geological knowledge of the site and the use of the extracted material. Based on these, we must choose which way to start optimally in the development.

Since the most gentle production method is rock sawing, and to reduce the number of machines, we plan to solve the production with a design that is capable of winning and transport.

## Acknowledgements

The described work/article was carried out as part of the „MIOCÉN kisléptékű kőzetjővesztő bányászati adapter prototípusának fejlesztése”, GINOP-2.1.7-15-2016-00463 project in the framework of the Széchenyi2020 Program. The realization of this project is supported by the European Union, co-financed by the European Regional Development Fund.



**GINOP-2.1.7-15-2016-00463**  
www.miocen.hu

„MIOCÉN kisléptékű kőzetjővesztő bányászati  
adapter prototípusának fejlesztése” projekt



## References

- Andras, I., Radu, S. M., Andras, A., Study Regarding the Bucket-Wheel Excavators Used in Hard Rock Excavations, *Annals of the University of Petroșani, Mechanical Engineering*, Vol. 18, pp. 11-22, (2016).
- Fülöp, V. G., Fülöp, G., Virág, Z., Ladányi, G., Horváth, S., Agoston, G., MIOCÉN kisléptékű kőzetjővesztő bányászati adapter prototípusának fejlesztése, 50. *Bányagépészeti és Bányavillamossági Konferencia*, poster, Balatongyörök, Hungary, in Hungarian, (2017).
- Mednyánszky, M., *Kőházak*, TERC Publisher, ISBN JT-1326, in Hungarian, (2017).
- Molnár, J., *Kőbányászat*. Educational Supplement in Hungarian, University of Miskolc, Institute of Mining and Geotechnical Engineering, Miskolc, (2012).
- Tomus, O. B., Rada, A. C., Study of the cutting forces and specific cutting resistance from the point of view of the cutting direction relative to stratification of the coal seam, *Annals of the University of Petroșani, Mechanical Engineering*, Vol. 19, pp. 143-148, (2017).
- Török, Á., Építészeti kőanyagok előfordulása és felhasználása a mai Magyarország területén a XVIII. századig. *A Miskolci Egyetem Közleménye A sorozat, Bányászat*, Vol. 74., pp. 137-155, in Hungarian, (2008).

# A two-stage macro based approach for developing aircraft engine components concessions based on surface morphing technologies

Rusu Robert<sup>a</sup>, Alexandru Tudor – George<sup>a\*</sup>, Monica Manole<sup>a</sup>

<sup>a</sup>Assystem Technologies, 7 Iuliu maniu Blvd., 061072 Bucharest, Romania

---

## Abstract

Computer Aided Engineering tools are widespread in the aerospace industry, being used in all the life cycle stages of an aircraft in order to numerically capture the behavior of parts and sub-assemblies subject to ground and flight loads. In the case of turbofan engines, apart from the design stage, simulation tools are found in a close relationship with physical geometry measurement test procedures, being used to support manufacturing changes from the baseline virtual prototypes. While such approaches are found at the maturity stage, being used in various configurations by teams geographically delimited around the world, the high degree of manual work involved together with the high level of repetitive task required lead to high amounts of time being spent on such projects with a low degree of knowledge based engineering being captured and re-used. The present paper addresses such issues by extending conventional simulation approaches with surface morphing capabilities that are embedded within computer aided engineering pre-processing software, as tools that can fill the gap between physical geometry measurements data and numerical simulation models. The given concepts are proved by means of a conceptual case study regarding manufacturing non-conformities occurring for a variable stator vane turbofan engine component.

*Keywords: Jet engines, Computer Aided Engineering, Non-Destructive testing, Morphing*

---

## 1. Introduction

The ongoing trends in the aerospace industry call for new airliners that can operate with lower noise levels and higher fuel efficiency across extended flight ranges (Graham et al., 2014). Apart from the structural aspects of a jet airliner, the engines represent a main concern in this sense, R&D efforts being focused on components that are lighter and stiffer. A wide range of alternative materials are currently in use in the design of stator and rotor components. Examples include (but are not limited to) metal matrix composites, hybrid-metallic materials and titanium alloys, yielding enhanced aerodynamic performances and high structural durability (Srinvas et al., 2018). To support integration of such materials in the design of aircraft engine components, virtual prototyping technologies benefit from the use of computer aided software (Ryazonov, 2016). Surface modeling capabilities embedded within Computer Aided Design (CAD) software assisted design engineers with the necessary tools for achieving innovative shapes for blade structures while the applicability of such design scenarios can be validated thanks to the wide scale use of Computer Aided Engineering software (CAE), based on numerical modeling and simulation methods (Bolda and Pupăză, 2018). The resulting design stage prototypes are subject to several manufacturing processes in order to achieve a compromise between the baseline and the physical structure, such that the efficiency, natural frequencies, strength and toughness requirements are met with respect to economical and manufacturability criteria (Amoo, 2012). From this point of view, conventional and non-conventional manufacturing processes are deployed (i.e. investment casting of a turbine blade, electrochemical machining of blade shrouds and electro discharge machining of groove face surfaces in axial compressor blades). The wide scale implementation of industrial robots together with the ongoing improvement of fault detection and diagnosis expert systems has significantly lowered manufacturing issues (Ivan et. al., 2015; Alexandru, 2001) Even so, the ever increasing complexity of aircraft engines, results in components that are prone to non-conformities (NC). For example, shrinkage of thin walled structures during casting can result in non-uniform wall thickness that can lead to stress redistributions (Dong et. al, 2017) while generating features by electro discharge machining can result in rim zones in the case materials with characteristics altered by mechanical or thermal effects are used.

---

\* Corresponding author. Tel.: +0-000-000-0000 ; fax: +0-000-000-0000 .  
E-mail address: talexandru@assystem.com



As a consequence, such non-conformities are susceptible crack initiation and propagation sites (Pramanik et. al., 2017). From an economical point of view, considering all out of tolerance components as scrapable parts, can result in low profit margins while from a technological point of view, performing rework (i.e. light machining and welding) does not guarantee on-time delivery of the final product. While some non-conformities cannot be acceptable without rework as they pose a threat to the structural integrity of the engines (i.e. internal cracks found in the proximity of stress concentration points), other non-conformities have no significant side effect as the impacted component can withstand damage throughout the life cycle of the engine (i.e. localized loss of thickness in low stress locations). Considering the high costs related to the manufacturing of aircraft engine components and the aerospace design philosophies, it is imperative to develop a concession approach, in order to prove that a component that is out of tolerance can be considered acceptable with or without further work performed. Physical geometry measurements supported by automated 3D scanning apparatus are well developed being used in wide scale for identifying geometrical tolerance deviations (Burghardt et al., 2017). Non-destructive testing (NDT) approaches are common for the inspection of internal (x-ray scan) and external manufacturing NC (penetrating liquids) (Bernoud and Mourad, 2011). Results from both inspection types are used for performing manufacturing flaws concessions based on analytical and numerical calculations. The first part of the work discusses about the concessions process workflow, describing a generalized approach adopted in the aerospace industry. The second part of the work presents the significance of CAE simulations in the concession processes, together with the most common methods used for developing concessions calculations. In the third part of the work, limitations of the existing methodologies are discussed, highlighting the need to tackle such issues by developing new approaches. The original contribution is illustrated in the last part of the work, consisting of a macro-based tool that performs a two-stage process for test reports data conversion and update of the baseline models. Automation of FEM editing is achieved by expanding the simulation models with surface morphing based on parametric surface definition capabilities and by combining FEM transformation commands found in most commercial pre-processing software. To prove the given concepts, a conceptual case study regarding the update of a baseline Variable Stator Vane (VSV) model is illustrated by the end of the work. LMS Samtech SAMCEF Solver suite is used due to its embedded geometric, FEM modeling, solving and post-processing capabilities.

## 2. Concessions workflow

The concession process is characterized by the use of inspection data in other to prove by analytical, numerical or design means that an out of tolerance component can withstand damage throughout the life cycle of the assembly it is part of. The method requires an identification of the applicable criteria and their relationship with the NC. For example, loss of thickness of a stator blade causes the mass of the component to change, developing a different dynamic behavior than that of the baseline. To verify the criteria, the dynamic calculations are updated to consider the thickness loss and the analysis is re-run in order to process the changes of the natural frequency and vibration mode shapes.

Major jet engines manufacturers successfully implemented and use concession approaches for components having a certain non-conformity threshold value. While the choice of tools, methods and guidelines is specific to each company, a general approach workflow is depicted in Fig 1. Test reports based on geometrical measurements or NDT are studied to identify if the manufactured component exceeds the tolerance values prescribed in the shop drawing. A certain threshold value is defined; such that aerodynamic criteria remain unchanged (pressure and temperature gradients are not impacted by the NC).

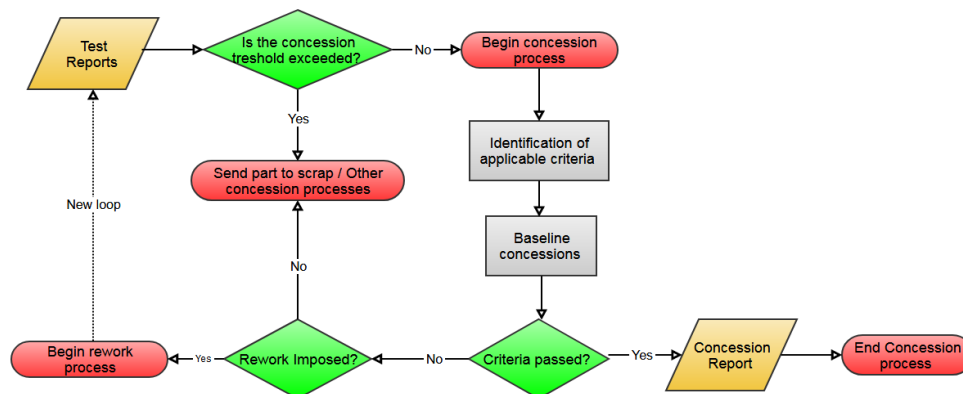


Fig. 1. A typical concession workflow structure applicable to aircraft engine components

If the manufactured parts exceed this value, either a different concession approach is used or the part is sent to scrap. The concession process represents a three-step approach:

- *Identification of applicable criteria*: based on the out of tolerance values, their location on the part and the type of NC, certain functional criteria are impacted. For example, a surface crack located on the trailing edge of an outlet guided vane significantly lowers the fatigue life of the impacted part;



- **Baseline concessions:** For each impacted criteria, an analysis is performed to determine if the NC can be acceptable as is (no rework is required), acceptable with further work performed or not acceptable (for parts that have NC or reworked NC that do not have the ability to maintain their structural reliability throughout the life cycle of the jet engine);
- **Concession report:** an overview of the calculations performed is presented in the concession report. This document serves as a basis for mounting the part as is or for performing further work.

### 3. Simulation models

CAE simulation models are widely in use in the complete life-cycle of a product in order to numerically capture the behavior of parts or assemblies subject to ground and flight load cases. To perform most common analysis types (i.e. static stress, modal, frequency response, eigenvalue buckling), a CAD geometric model is subdivided in elements (meshed structure). Each element consists of set of nodes that are linked together to close the computational model, where each node typically represents an integration point. Both simulation metadata and results stand at the core of the concession processes, being used as baseline references for developing justification calculations. Several concession approaches are available:

- **Analytical calculations:** changes from the baseline section result in the increase of the mechanical stresses if the section loss occurs or decrease of the stresses and/or load redistribution if the out of tolerance value is positive. In this case, results are extracted from the baseline simulation models and are multiplied by specific factors. Such factors are based on in-house knowledge (i.e. experimental assessment of mechanical stresses on out of tolerance parts) or on simplifying assumptions (i.e. stress increase factor are derived from the critical section area ratio) – see Fig 2. - a.
- **CAD/CAE based studies:** a reverse process can be performed to geometrically represent the area where the NC is localized. Various densities of mesh can be applied to refine the calculation model around the NC. Loading is applied under the form of displacements extracted from the baseline simulations that are applied to the boundaries of the model – see Fig 2 - b.
- **CAE simulations update:** each element consists of a set of nodes localized in the global model space by three coordinates (CX; CY and CZ). The free faces of an element (for 2D and 3D element types) define the boundaries of the outer skin for a solid body. To update the simulation models without performing a re-mesh of the structure, nodal coordinates should be updated to take in to account the NC. An example is illustrated in Fig 2 –c. The free faces of a 3 node 3D tetrahedron element are displaced such that the baseline mesh is translated to a modified mesh that captures a shape deviation.

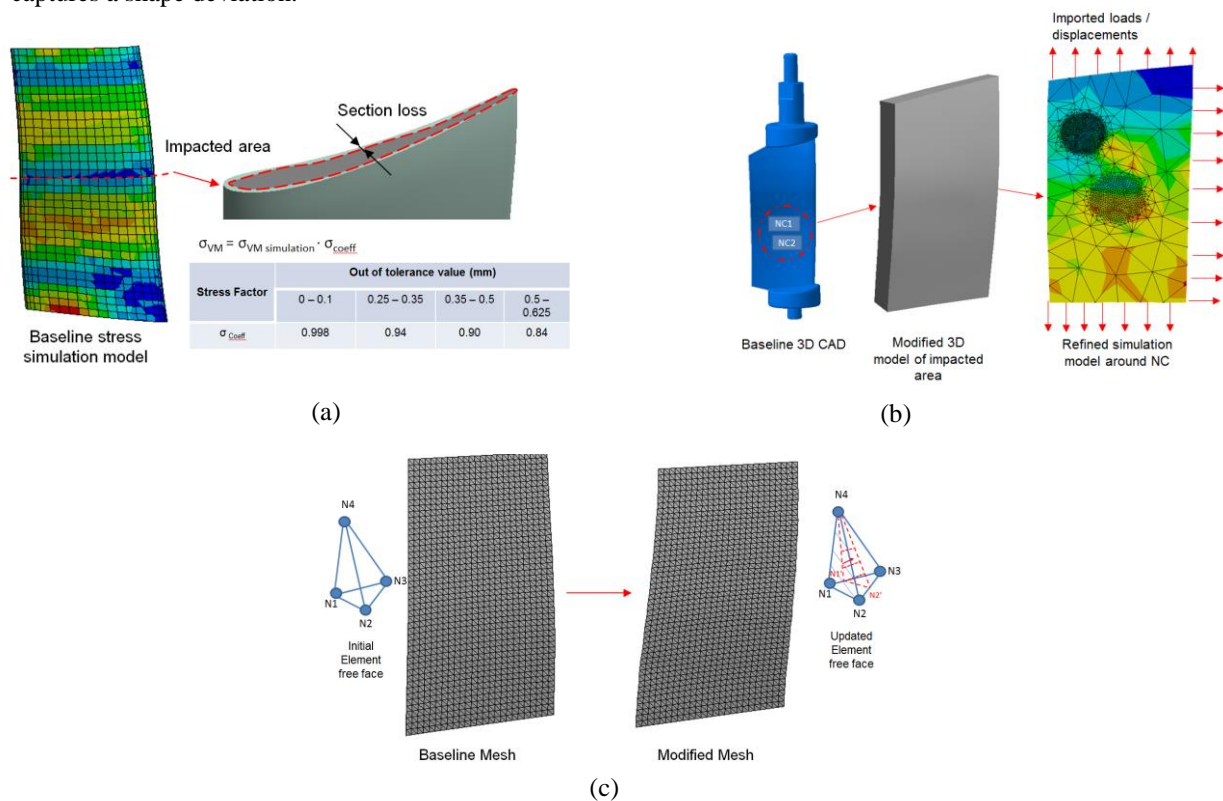


Fig. 2. Concession approaches (a) analytical solution approach; (b) CAD/CAE based studies; (c) CAE simulations update

#### 4. Limiting aspects of concession approaches

All concession approaches can be considered valid for supporting both manufacturing and R&D activities in the field of aircraft engines. Even so, specific issues arise that require a closer observation:

- *High level of repetitive tasks* – All types of concession processes involve a high degree of manual work to be performed. Most of the times, the selection of the impacted area, extraction of results from the baseline and / or generation of the mesh involve a high degree of repetitive tasks to be performed. This results in a high probability of errors to occur, requiring extra check to be performed;
- *Low traceability* – The choice of extractions, selection of the impacted area together with the mesh methods applied are a result of the engineer's judgment. Being hard to define a standard approach, the same NC can be interpreted differently by different engineering teams, leading to different results and consequently, low traceability;
- *Low level of knowledge based engineering* – concession processes represent a rich source of knowledge modeling and sourcing. Even so, not much attention is paid to the development of knowledge based engineering approaches oriented for concession processes. As a consequence, small amounts of knowledge are re-used in such projects.

#### 5. Proposed approach

The proposed approach consists of a macro written in Microsoft Excel VBA application that performs a two stage process – see Fig 3. At first, test reports are read in .CSV file format. Considering that the test reports have a standard structure, data is read from specific lines. Each out of tolerance point is used to update a baseline script written for SAMCEF Bacon module that has the aim of generating a parameterized surface that recreates the physical shape of the exterior solid faces. In the next step, a baseline CAE simulation model input file is read and stored in the memory. A graphical user interface was developed for simple control and preview of working files – see Fig 4.

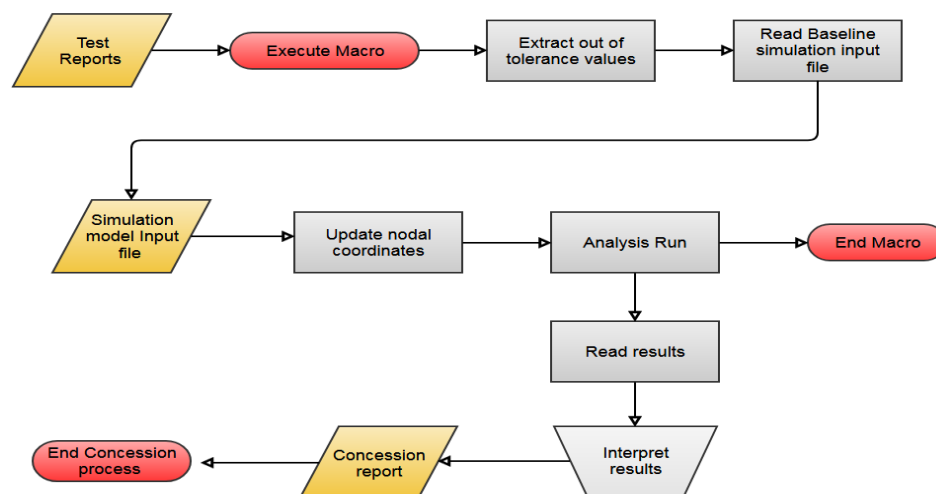


Fig. 3. Two-stage macro based approach

Non-conformity Analysis Interface		
<b>Data Input</b> <div style="border: 1px solid black; padding: 2px; margin: 5px;">.CSV List</div> <p>Delimiter used is: Point</p> <div style="border: 1px solid black; padding: 2px; margin: 5px;">SAMCEF .DAT</div> <p>Loaded file is: C:\SAM_SCRATCH\VSF.DAT</p> <p>Load Status is: <span style="background-color: #90EE90; padding: 2px;">OK</span></p>	<b>Ouput</b> <div style="display: flex; flex-direction: column; gap: 5px;"> <input type="radio"/> BACON Surface Preview           <input type="radio"/> BACON Projected Mesh           <input type="radio"/> BACON Post-processing list         </div> <div style="border: 1px solid black; padding: 2px; margin-top: 10px;">Generate Output</div>	<b>Analysis Run</b> <div style="border: 1px solid black; padding: 2px; margin: 5px;">Run Solution</div> <div style="display: flex; align-items: center; gap: 10px; margin-top: 5px;"> <input checked="" type="radio"/> BACON Interactive Run         </div>

Fig. 4. Graphical user interface

In the next step, surface morphing is performed in order to map the exterior faces of the baseline mesh over the defined surface – see Fig 5. Note that exaggerated out of tolerance values were used for visualization purposes.

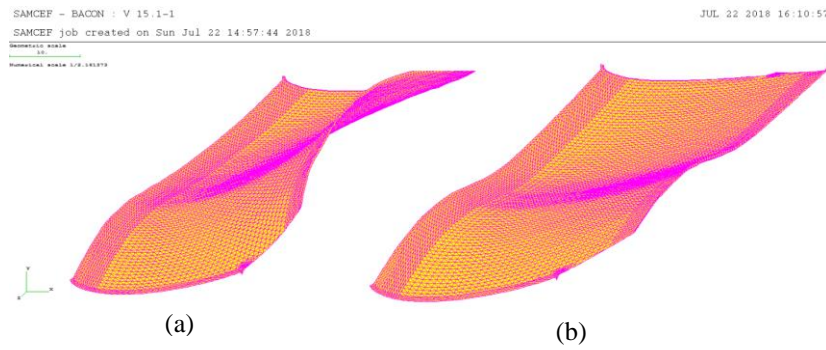


Fig. 5. Preview of Morphing operations performed for a VSV blade (a) Mesh after performing morphing operations; (b) Baseline mesh

The modified nodal coordinates recreate the physical shape of the out of tolerance components allowing for high-accuracy studies to be performed. Furthermore, resulting script files can be stored in databases to be re-used for similar cases. In the last step, a batch process takes place for running the analysis considering the new nodal coordinates.

## 6. Conceptual case study

A VSV component was subject to casting NC, resulting in a series of shape deviations occurring on the center section of the blade. Geometry inspection was carried out and results were saved to a standard .CSV extension file. The baseline mesh is presented in Fig 6. The workflow discussed in the previous chapter is applied. In this case, a static stress analysis is performed using SAMCEF ASEF module. High fidelity results are achieved by the end of the loop – see Fig 7. Compared to the baseline, the Von-Mises stress gradients and peak values have migrated, resulting in a new stress state that takes place due to the NC.

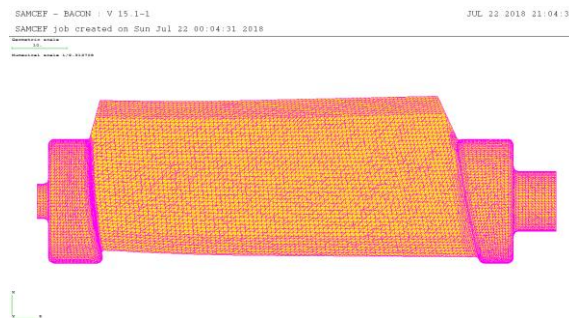


Fig. 6. Preview of the baseline 3D mesh

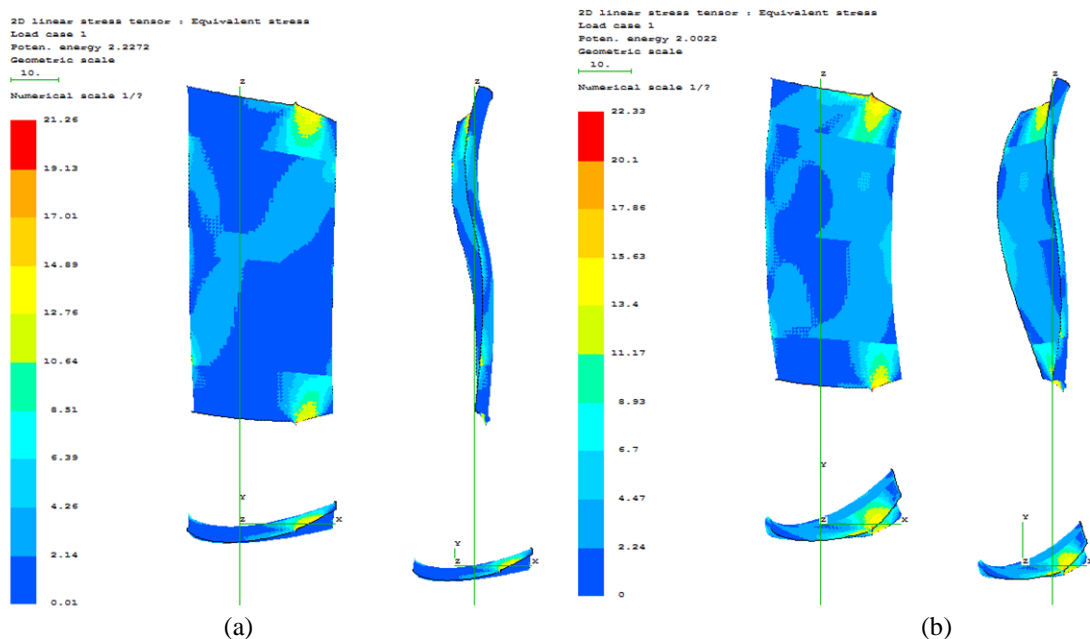


Fig. 7. Unaveraged Von-Mises stress criteria (a) Baseline simulation; (b) Updated simulation model

The baseline mesh and results of the analysis are further used as input data for 3<sup>rd</sup> party tools used for verifying specific functional criteria.

## 7. Conclusions

The present paper presents the workflow and approaches available for aircraft engine components concession processes. The identified issues are tackled by deploying a two stage macro based approach that automates the CAE simulation update process by reading data from test reports and generating a geometric surface that captures the real shape of the non-conformal product. Morphing technologies are used to map the baseline mesh over the resulting surface. The approach lowers the amount of repetitive tasks, while enhancing traceability and knowledge based engineering capabilities.

## References

- Alexandru, A. A real time knowledge-based approach for fault diagnosis and its applications. *International Journal of COMADEM*, Vol. 3, Iss. 2, pp. 32-38 (2001).
- Amoo, L. M., On the design and structural analysis of jet engine fan blade structures. *Progress in Aerospace Sciences*, Vol. 60, pp. 1-11 (2012).
- Bennoud, S., Mourad, Z. The non destructive testing methods applied to detect cracks in the hot section of a turbojet. *In Applied Mechanics and Materials*, Vol. 61, pp. 79-83 (2011).
- Bolda, M., Pupăză, C., Dynamic simulation of industrial robots behaviour using integrated software procedures. *Proceedings in Manufacturing Systems*, Vol. 13, Iss. 1, pp. 39-46 (2018).
- Burghardt, A., Kurc, K., Szybicki, D., Muszyńska, M., Szczęch, T. Robot-operated inspection of aircraft engine turbine rotor guide vane segment geometry. *Technical Gazette*, Vol. 24, Iss. 2, pp. 345-348 (2017).
- Dong, Y. W., Li, X. L., Zhao, Q., Yang, J., Dao, M. Modeling of shrinkage during investment casting of thin-walled hollow turbine blades. *Journal of Materials Processing Technology*, Vol. 244, pp. 190-203 (2017).
- Graham, W. R., Hall, C. A., Morales, M. V., The potential of future aircraft technology for noise and pollutant emissions reduction. *Transport Policy*, Vol. 34, pp. 36-51 (2014).
- Ivan, A. M., Nicolescu, A. F., Avram, G. C., Stan, L. Robotic deburring cell virtual prototyping. *Proceedings in Manufacturing Systems*, Vol. 10, Iss. 4, pp. 183-188 (2015).
- Pramanik, A., Dixit, A. R., Chattopadhyaya, S., Uddin, M. S., Dong, Y., Basak, A. K., Littlefair, G. Fatigue life of machined components. *Advances in Manufacturing*, Vol. 5, Iss. 1, pp. 59-76 (2017).
- Ryazanov, A. I., Automated 3D modeling of working turbine blades. *Russian Engineering Research*, Vol. 36, Iss. 9, pp. 751-754 (2016).
- Srinivas, G., Raghunandana, K., Shenoy, B. S., Recent developments in turbomachinery component materials and manufacturing challenges for aero engine applications. *In IOP Conference Series: Materials Science and Engineering*, Vol. 314, pp. 1-15 (2018).

## Increasing the quality of the well drilling process by finite element analysis of the drilling fluid flow parameters

Sorin Mihai Radu<sup>a</sup>, Florin Dumitru Popescu<sup>a</sup>, Andrei Andraș<sup>a\*</sup>, Ildiko Kertesz Brînaș<sup>a</sup>,  
Ovidiu – Bogdan Tomuș<sup>a</sup>

<sup>a</sup> University of Petroșani, Department of Mechanical, Industrial and Transport Engineering, str. Universității 20, Petroșani, 332006

---

### Abstract

Drilling is a highly demanding machining process due to complex variables like tool geometry, material failure and drilling fluid behaviour. In order to increase the quality of this process, a model was developed using SolidWorks, in order to simulate the behaviour of the drilling fluid flow for different speed and pressure values, from the point of view of the transport of debris out of the wellbore, prevention of external fluid influx, and the maintenance of wellbore stability. The results of the simulations demonstrate the effects of drilling fluid flow parameters on drilling and also confirms the capabilities and advantages of FEM simulation of the drilling process.

**Keywords:** Drilling, Drilling fluid, Simulation, FEM, Wellbore;

---

### 1. Foreword

Well drilling is a technology used from ancient times and is employed in many fields, such as:

- geological exploration;
- oil and gas extraction;
- underground water extraction;
- mining shaft sinking;
- geotechnical research.

The well is an excavation having a cylindrical shape. The wells can be vertical or inclined ones.

The well drilling is a complex operation which consists in rock removal and the transportation of detritus (debris) away from the well to the surface. The drilling is performed with the equipment called drilling rig.

The drilling rigs can be:

- heavy drilling rigs, with high actuating power, the drilling depth reaching thousands of meters and the well diameter ranges from hundreds of millimetres to 7000 mm;
- small depth drilling rigs (lightweight drilling rigs) with reduced actuating power, and drilling depth less than 1000 – 2000 m, with small well diameters.

The purpose of the drilling operation determines the kind of drill bit used, which differs in the manner in which the rock is removed on the bottom of the well, as follows:

- for the exploration wells, which aim to obtain samples of rocks, the rock cutting is performed in an annular cross section, using a bit named coring drill bit (Figure 1), the drilling is called coring drilling and the rock sample obtained is named core specimen, which is a cylindrical piece of rock, which is useful for the knowledge of the geological structure of the location's subsurface.
- for the wells drilled with the purpose of extraction (oil, gas, water) or mining infrastructure (transport or ventilation shafts) the rock removal on the bottom of the well is made on full circular cross section, and the corresponding tool is the conventional drill bit (Figure 2). In both cases the drill bit is actuated through the drill string by the rotating table which is located at the top of the well and is a component of the drilling rig. The detritus is transported away using the so-called drilling fluid or mud.

---

\* Corresponding author. Tel.: +40-722366653,  
E-mail address: andrei.andras@gmail.com



Fig.1 Coring drill bit



Fig.2 Conventional drill bit (tri-cone type)

The most frequently used drilling method is the rotary one, with debris transported to surface by fluid circulation. The drilling process is a continuous one, the rock removal and the detritus transportation being performed simultaneously. (Figure 3).

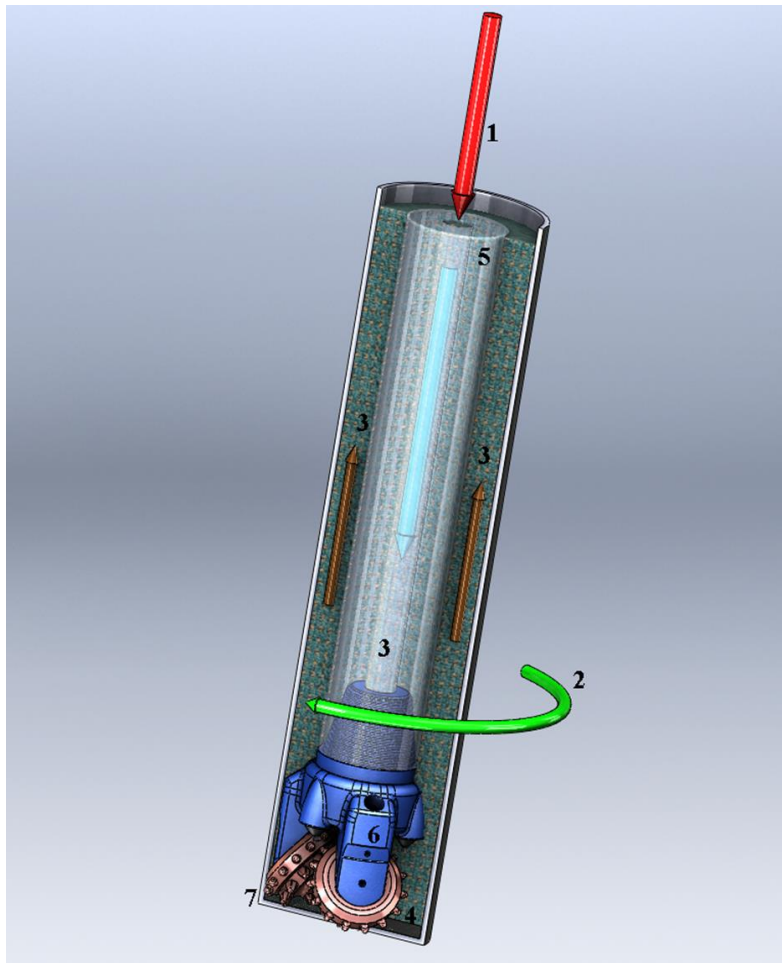


Fig.3 The principle of drill bit's operation (1 – thrust force, 2 – torque, 3 – fluid flow, 4 – detritus, 5 – drill string, 6 – drill bit, 7 – bottom of well)

## 2. The analysis of the drilling fluid behaviour by Flow Simulation tool of SolidWorks

We analysed the drilling fluid behaviour for a rig that has a three-cone drill bit with drilling fluid circulation channels. The analysis was done in SOLIDWORKS software, using the Flow Simulation tool. The assembly analysed is shown in Figure 4.



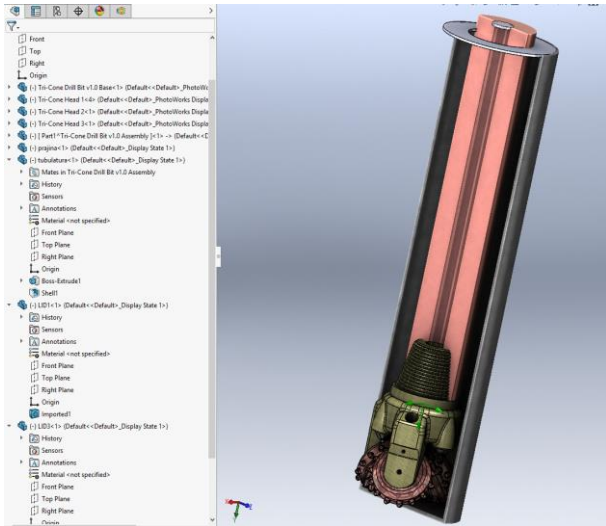


Fig.4 The assembly on which the analysis was conducted

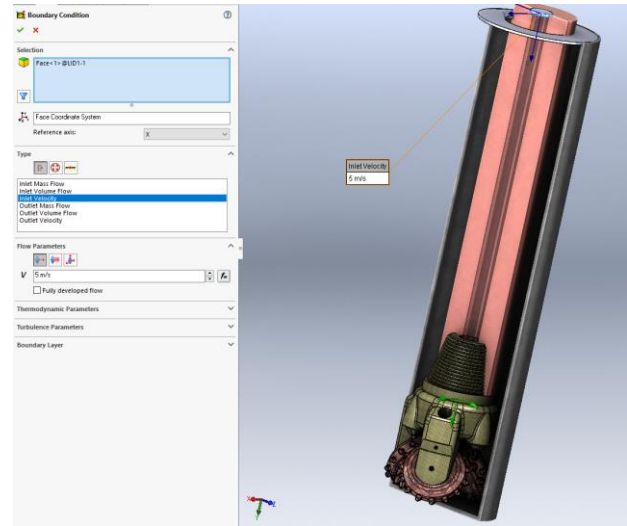


Fig.5 Set-up of the inlet velocity of the drilling fluid into the drill string

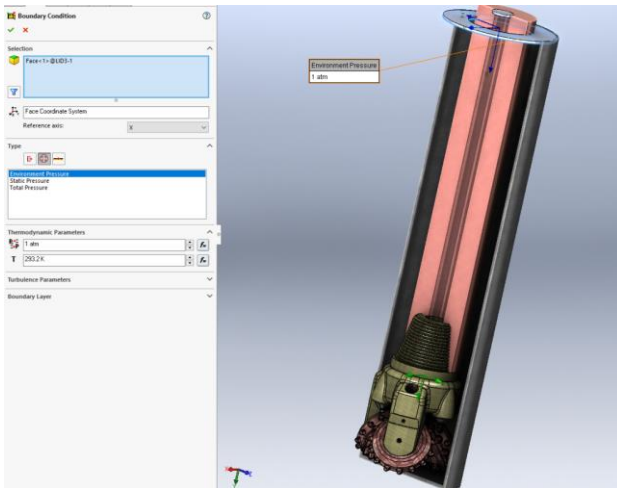


Fig.6 Set-up of the upper pipe pressure

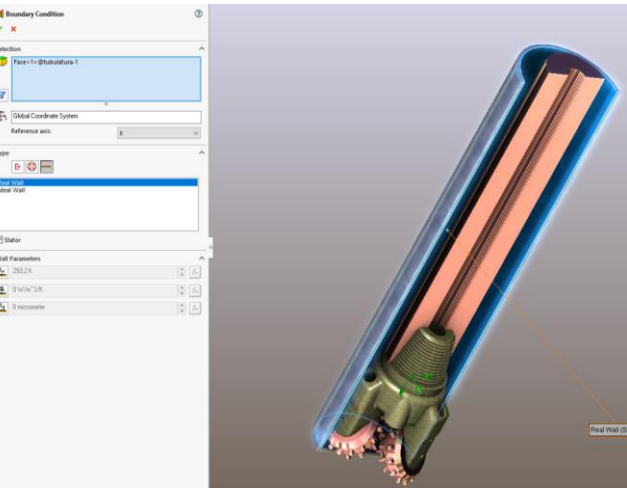


Fig.7 Set-up of the stator limit corresponding to the internal surface of the piping

Two parts named LID1 and LID3 were added in order to "close" the drilling fluid circuit at the top of the drill string and of the duct (casing) respectively. Their role is essential in case of an internal analysis because they determine the limits of the scope of analysis. Water was considered as drilling fluid.

We have imposed three conditions at the separation limit of the analysed field: the inlet velocity into the string (Figure 5), the upper pipe pressure (Figure 6) and a stator limit corresponding to the internal surface of the piping (Figure 7).

The rotating movement of the drill-bit and of the drill-string was simulated by defining into the assembly of two areas of rotation, to "encompass" the drill-bit and the drill-string respectively. In Figure 8, these rotation areas are set to transparent while in the final presentation of the results their attribute was changed to "hidden".

To these two areas we imposed an angular velocity of  $105 \left[ \frac{rad}{s} \right]$  or  $1000 \left[ \frac{rot}{min} \right]$  (figure 9).

Figure 10 shows a screenshot of the drilling-fluid behaviour in the defined conditions. It can be seen that its speed increases considerably at the exit of the three nozzles. This result highlights the hydrodynamic role of the drilling fluid.

By analysing the trajectory lines of the drilling fluid it can be concluded that in the annulus (space between the drill-string and the tubing) the fluid has a helical motion from the bottom to the top of the bore-hole. This helical trajectory is generated by the rotation movement of the drill-string and bit, which act as rotors for fluid pumped into the well.

Figure 11 shows the pressure variation of the drilling fluid. Similar to figure 10 it can be seen that the pressure rises at the bottom of the well, which also highlights the hydrodynamic role of the drilling fluid.





Fig.8 The defined areas of rotation

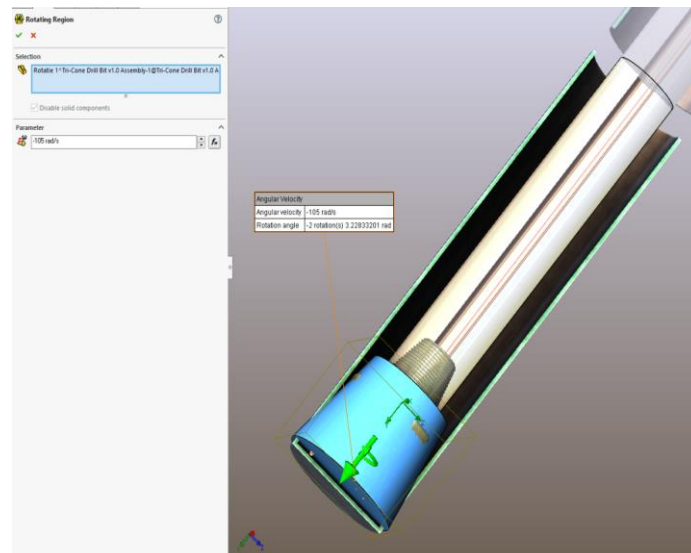


Fig.9 Defining the angular velocity of the areas of rotation

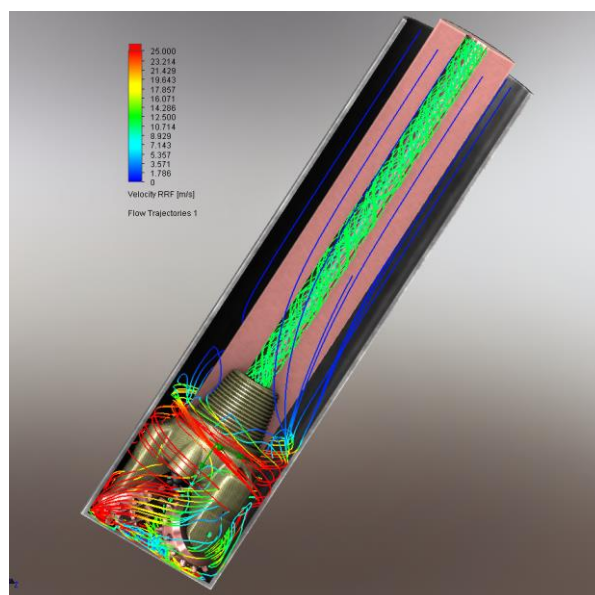


Fig.10 Speed of the drilling fluid

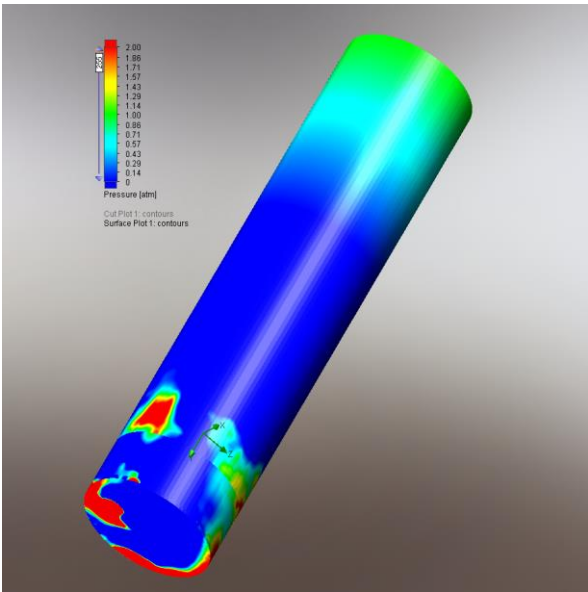


Fig.11 Pressure of the drilling fluid

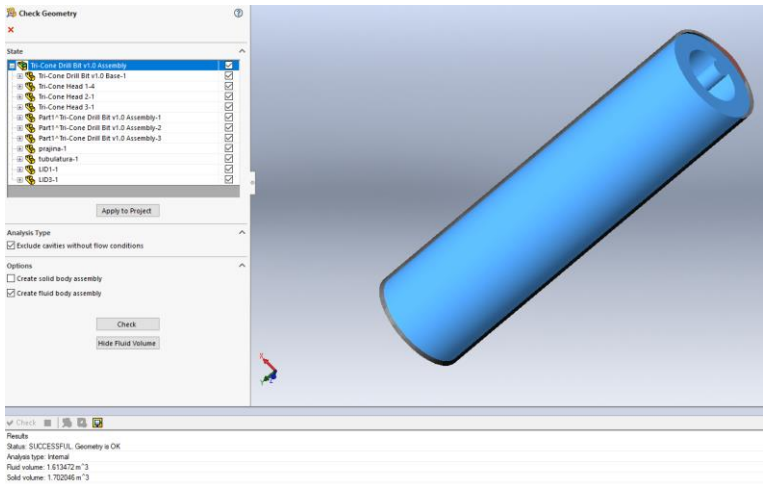


Fig.12 Determination of the drill-fluid volume



Fig.13 Sections through the drill-fluid “part”

SOLIDWORKS software allows the determination of the fluid volume that is used in the conducted analysis. Figure 12 shows this option. For the example considered a volume of the drill-fluid in amount of aprox. 1.61 cubic meters was considered. In figure 13 the drill-fluid volume was considered as a SolidWorks part that was sectioned by two planes.

### 3. Conclusions

The study of the behaviour of the drilling fluid using FEA shows that:

- The hydrodynamic role of the drilling fluid, which, because of the increase of velocity and pressure at the exit nozzles dislocates the debris from the bottom of the borehole
- The hydrostatic role of the drilling fluid, because the pressure of it on the walls of the well prevents the collapse of loose formation of rocks as well penetration of the borehole by external fluids.
- The power conducting and informative role of the drilling fluid, which acts as an energy transmitter towards the drill-bit and also permit the analysis and information gathering from the evacuated debris.

Results of present and future research can be used in the design of drill strings, by replacing the standard cycle of designing → prototyping → testing into a simpler and more cost-effective process of prototyping only for the validation of the final design. Obviously, the final goal is the building of improved drill strings and drill bits in order to increase the quality of the well drilling process.

### References

- Costin, I., *Instalații pentru foraj de mică adâncime*, Editura Tehnică, București, 1972.
- Dimirache, G., Zamfir, V., *Ingineria sistemelor mecanice*, Editura Focus, Petroșani 2002.
- Iliaș, N., Zanfir, V., Andraș, I., Ș.A., *Mașini miniere. Exemple de calcul*, Editura Tehnică, București. 1993.
- J. Ed Akin, *finite element analysis concepts via solidworks*, World Scientific, 2009.
- Kovacs, I., Iliaș, N., Nan, M.S., *Regimul de lucru al combinelor miniere*, Editura Universitas, Petroșani, 2000.
- Kurowski, P.M., *Engineering Analysis With Solidworks Simulation*, 2015.
- Lari, I., *Garnitura de foraj*, Editura Tehnică, București, 1961.
- Marian, I., *Utilaje de încărcare și transport minier*, Editura Tehnică, București, 1991.
- Mălureanu, I., *Geofizică de sondă, Vol I*, Editura Universității Petrol - Gaze Din Ploiești, 2007.
- Nan, M.S., *Parametrii procesului de excavare la excavatoarele cu rotor*, Editura Universitas, Petroșani, 2007.
- Zamfir, V., Dimirache, G., *Teoria mecanismelor pentru sisteme automate și roboți industriali: notițe de curs*, Editat La Universitatea Din Petroșani, 1996.

## Simulation and modelling of the forces acting on the rotor shaft of BWEs, in order to improve the quality of the cutting process

Sorin Mihai Radu<sup>a</sup>, Florin Dumitru Popescu<sup>a</sup>, Andrei Andraș<sup>a\*</sup>, Ildiko Kertesz Brînaș<sup>a</sup>,  
Ovidiu – Bogdan Tomuș<sup>a</sup>

<sup>a</sup> University of Petroșani, Department of Mechanical, Industrial and Transport Engineering, str. Universității 20, Petroșani, 332006

---

### Abstract

BWEs used in open pit coal mining are subjected to excessive loads during cutting because of the interaction between the working face and the bucket wheel's components. High loads and unexpected shocks produce downtimes, increased wear, or severe damage of the BWE components or operational subsystems, leading to increased energy consumption, lower production rate and, finally, increased mining costs. A study of the forces acting on the shaft of the bucket wheel was conducted, using computerised modelling and simulation, in order to reduce the mentioned issues and improve the quality of the excavation process.

*Keywords:* BWE, Rotor shaft, Cutting process, Simulation, Forces;

---

### 1. Introduction

The bucket wheel excavator (BWE) is a machine with continuous operation which cuts the rock with the help of the buckets installed on the rotor, performing at the same time the transfer of the excavated material to the main conveyor, with the help of the conveyor belts installed on its boom. The operating equipment is the rotor (bucket wheel) which performs a rotation movement in vertical plane and, with the help of the boom, a horizontal pivoting movement and a vertical ascendant – descendent movement. In this paper we present a modality of determining the operation power of an excavator rotor using numerical methods. The aim of approaching some virtual models which allow the analysis of the operation of some components of the rotor excavator resides in the improvement of the cutting – loading system, the reduction of the specific energy consumption during the cutting operations while maintaining the installed power for the operation of the rotor and the increase in the excavation capacity, respectively the degree of intensive use of the excavator.

### 2. Definition and calculus of the excavation parameters

The method proposed for the calculus of the operation power of the rotor has been applied to a model EsRc 1400 excavator. This type of excavator is used in the lignite mine pits in the coal fields in Oltenia.

The geometric characteristics regarding the positioning of the rotor and the rotation mechanism are presented in figure 1 where the notations employed carry the following significance:

- $H_s$  – the height of the rotation axis of the boom as against the operating level of the excavator;
- $L_{sp}$  – the distance between the rotation axis of the boom and the rotation axis of the upper platform;
- $L_p$  – the pivot length of the boom;
- $H_{sp}$  – the distance between the rotation center of the rotor and the lower surface of the boom;
- $H_{sp}$  – the distance between the rotation center of the rotor and the symmetry vertical plan of the boom;
- $\delta$  – the angle between the longitudinal axis of the rotor and the pivoting axis of the boom.

---

\* Corresponding author. Tel.: +40-722366653,  
E-mail address: andrei.andras@gmail.com

The arm of the excavator performs in vertical plane an ascendant and descendent movement around the rotation axis of the boom (figure 1). Horizontally, the rotation movement occurs around the rotation axis of the upper platform with the pivoting speed  $V_p$  (figure 2). From a technological and also energetic point of view, the plans in which the two rotations appear (ascendance – descendance and pivoting) must be vertical, respectively, horizontal. The vertical and horizontal deviation must not exceed 3,50 – 4,50.

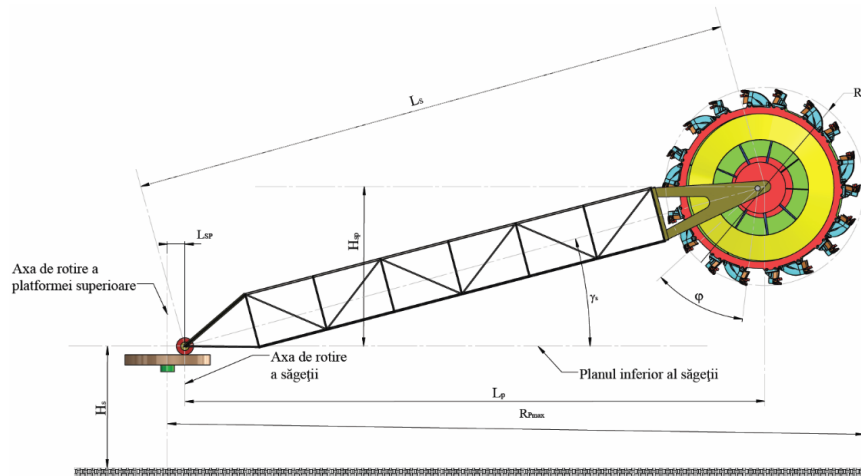


Fig.1 The geometric characteristics of the arm - rotor system, side view

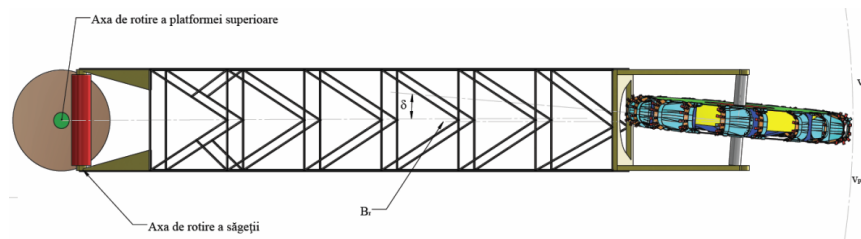


Fig.2 The geometric characteristics of the arm - rotor system, view from above

Figure 3 illustrates the case of the excavation of four slices, numbered 1, 2, 3 and 4. For each of these slices, the pivoting radius is modified. For this reason, it is necessary to correlate the pivoting speed with the position of the rotor.

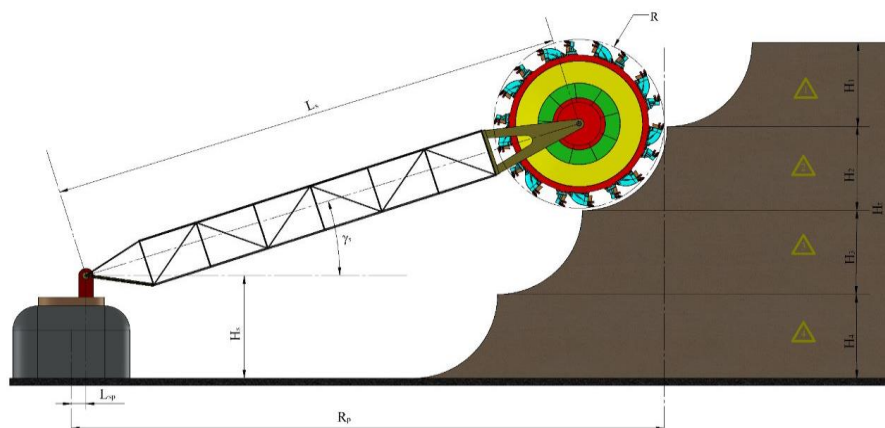


Fig.3 Excavation of slices

### 3. Calculus of the force and energetic characteristics

During the excavation process, the energy consumption at the level of the bucket wheel has two major components:

- the energy necessary for cutting the material to be excavated;
- the energy necessary for lifting the loose material resulted from cutting with the help of the buckets.

Between the two of the components presented above, the energy necessary for cutting the material is predominant, representing 60 ... 90% of the energy necessary for operating the bucket wheel.

Determining the energy and power necessary for operating the bucket wheel under certain functioning circumstances is essential for:

- the selection of excavators from an existent lot;
- the design of new excavators;
- the design of the new cutting – loading systems for the existent excavators.

The calculus of the power necessary for cutting with rotor excavators can aim at:

- determining the dependence of the power on the parameters of the operating regime for a given excavator;
- optimizing the energetic regime by accomplishing a cutting capacity at minimum energy consumption;
- determining the dependence of the power absorbed by the cutting – loading system on the cutting capacity, respectively the pivoting speed in the working front.

For the BWEs the force characteristics refer to:

- the forces which act on the bucket represented by:
  - the cutting force  $F_x$  which operates according to a direction tangent to the trajectory of the bucket;
  - the penetration force  $F_y$  which operates according to a normal direction to the trajectory of the bucket;
  - the lateral force  $F_z$  which operates according to a binormal direction to the trajectory of the bucket.
- the forces which act on the rotor are represented by:
  - the resultant cutting force  $F_{xR}$ ;
  - the resultant penetration force  $F_{yR}$ ;
  - the resultant lateral force  $F_{zR}$ .

The energetic characteristics refer to:

- the power necessary for excavation  $P_{ex}$ ;
- the power necessary for lifting the material  $P_r$ ;
- the power necessary to pivot the upper platform of the excavator, the boom and the rotor  $P_p$ .

The force and energy parameters depend on time and the characteristics of the dislocated chip. In practice, average values are employed so that we have:

According to the above information, the power necessary to drive the rotor will display the expression:

$$P = \frac{P_{ex} + P_r}{\eta_t} \quad (1)$$

where  $\eta_t$  represents the efficiency of the engine – bucket wheel transmission.

Thus, the following results:

$$P = \frac{1}{\Delta t \cdot \eta_t} Q_T \left[ \frac{k_{uz} \cdot K_e}{k_a} + \frac{1}{\eta_r} \left( D - \frac{H}{2} - \frac{2}{3} h_c \right) \rho_a \cdot g \right] \quad (2)$$

where:

- $Q_t$  - the theoretical excavation capacity (3280 m<sup>3</sup>/h);
- $D$  - the cutting diameter of the rotor (11,5 m);
- $H$  - the height of the bench (7,5 m);
- $k_{uz}$  - the wear degree of the teeth (1,2);
- $K_e$  - the specific cutting resistance (60 N/cm<sup>2</sup>);
- $k_a$  - loosening coefficient (1,35);
- $\eta_t$  - transmission efficiency (0,85);
- $h_c$  - the active height of the bucket (0,84 m);
- $\rho_a$  - loose rock density (1,3 – 2 t/m<sup>3</sup>).

After applying the relation (2), results a value of the operation power of the excavator rotor of 314 kW.

#### 4. Proposing a method of determining the operation power of the rotor of a bwe through modelling and simulation

The method presented in the previous section, based on mathematical relations and approximations is susceptible of errors leading to results which are not in accordance with reality. The development of the methods of modelling and simulation accomplished with packages of specialized integrated programs recorded lately offers the possibility of a holistic approach of the mechanical systems of the type presented in this paper, in which, the mechanical phenomena are solved intrinsically, without resorting to simplifying hypotheses which can affect the accuracy of the results.

In order to avoid the problems described previously, we have created the model of an excavator rotor using the SOLIDWORKS package. The analysed rotor is equipped with 9 cutting – loading buckets and 9 cutting buckets. A screenshot of the created model and the points of application of the resultant forces which operate the bucket are presented in figure 4. We considered the resultant forces produced by the cutting strength of the rock (for the buckets which are in the cutting process at a certain moment), the forces resulted from the weight of the material in the buckets and the inertia forces which appear when the buckets are discarded (these are determined directly by the application we have used).

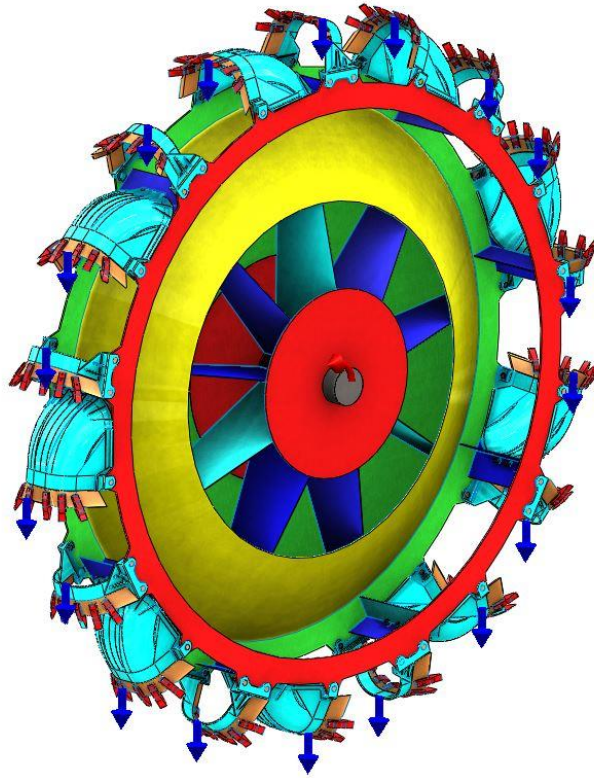


Fig.4 Screenshot of the bucket wheel

Figure 5 illustrates the diagram of time variation of the forces which drive the cutting – loading bucket.

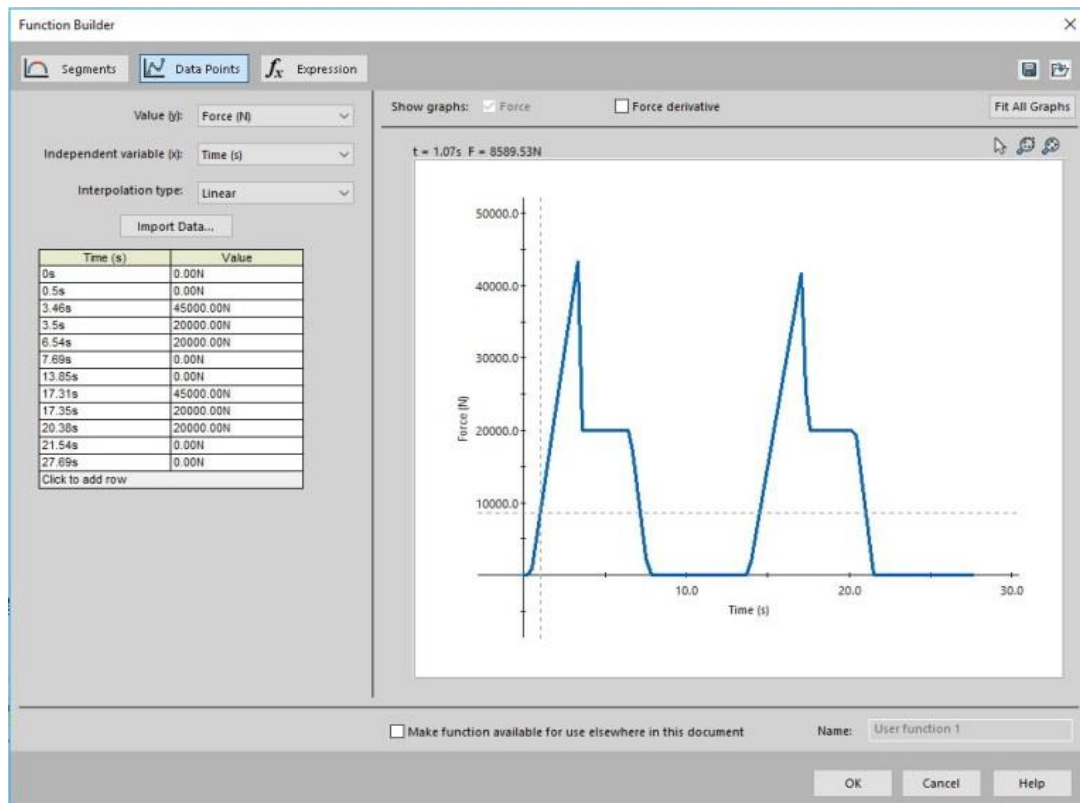


Fig.5 Diagram of time variation of the forces driving the cutting – loading bucket

Figure 6 presents the diagram of time variation of the forces which drive the cutting bucket. It can be noted that in the diagram in figure 6 the stages of lifting and discarding the bucket.



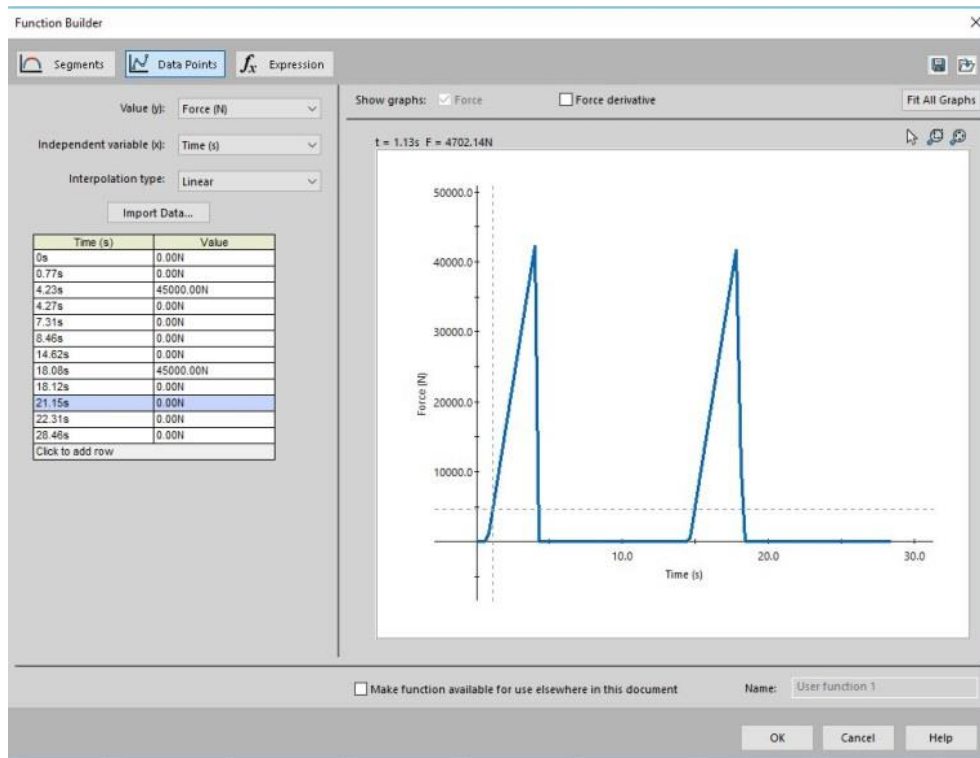


Fig.6 Diagram of time variation of the forces which drive a cutting bucket

The forces which drive the buckets are gapped with a short time interval of 1,54s, and the revolution of the rotor is 4,33 rot/min. Overlapping the forces which are gapped, we obtain for the duration of two complete rotations (27,69 s), the time variation of the operation power presented in figure 7.

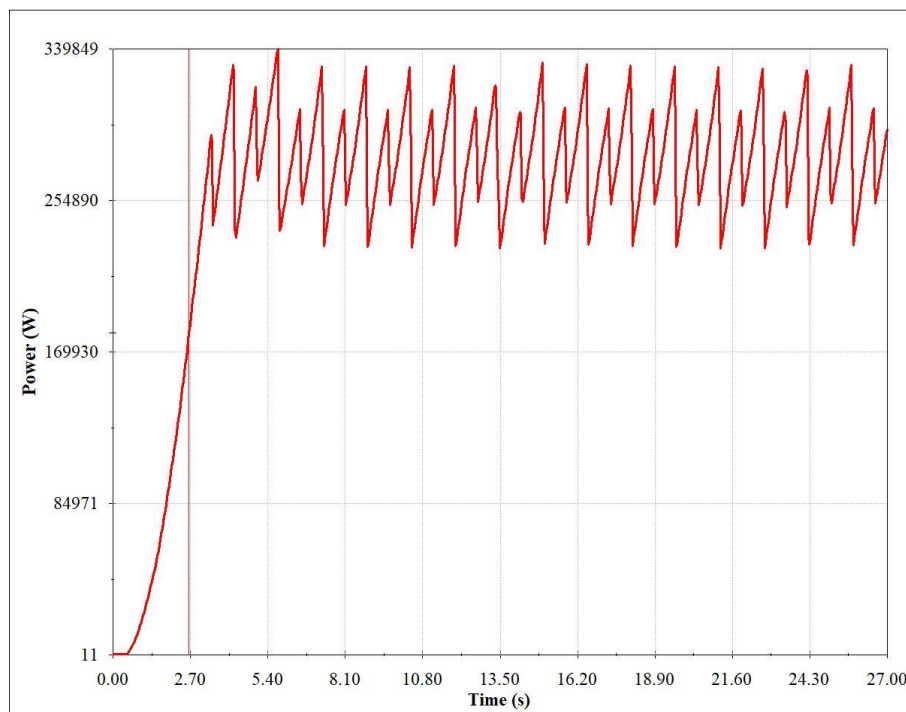


Fig.7 Time variation of the operating power

This figure shows that the power fluctuates between the limits of 240 kW and 340 kW, the average value being of 290 kW. The fact that this value is close to the value obtained through the classic calculus method presented in the previous section is not surprising, as we have considered the same characteristics of the tool and the excavated rock. Unlike the classic method, the presented method displays, besides the high accuracy, the advantage of illustrating the time variation of the power which can be useful in the dynamic analysis of the support structure of the excavator.

## 5. Conclusions

In this paper we propose a modality of determining the operation power of the rotor of an excavator through numerical methods.

The method is based on virtual models which allow the analysis of the functionality of the components of rotor excavators in order to improve the cutting – loading system, to reduce the specific energy consumption during cutting while maintaining the minimum installed power of operation of the rotor and to increase the excavation capacity.

We have presented a model of a rotor created with the SOLIDWORKS package with 9 cutting – loading buckets and 9 cutting buckets.

We have considered the resultant forces produced by the rock cutting strength (for the buckets which are in the cutting process at a certain moment), the forces determined by the weight of the material in the buckets and the inertia forces which occur when the buckets are discarded (these have been determined directly by the application employed).

The power calculated with the presented method fluctuates between the limits of 240 kW and 340 kW, the average value being of 290 kW, close to the value of 314 kW obtained with the classic method, the difference being reasonable as it refers to the same characteristics of the tool and the excavated rock.

Unlike the classic method, the presented method displays, besides the higher accuracy, the advantage of illustrating the time variation of the power which can be useful in the dynamic analysis of the support structure of the excavator.

As the presented method is based on numerical calculus methods, it displays a feature of generality, being applicable to any type of rotor excavator and rock characteristics.

## Acknowledgements

This research was (partially) carried out in the framework of European Union Research Found for Coal and Steel research project RFCR-CT-2015-00003-BEWEXMIN “Bucket wheel excavators operating under difficult mining conditions including unmineable inclusions and geological structures with excessive mining resistance”.

## References

- Kovacs, I., Nan, M.S., Andraş, I., Jula, D., *Stabilirea regimului extrem de funcționare a excavatoarelor cu roată portcupe*. Lucrările științifice ale Simpozionului Internațional „Universitaria ROPET 2002” 17-19 oct.2002 Petroșani – Inginerie mecanică
- Kovacs, I., Nan, M.S., Andraş, I., Jula, D., *Study of the working regime of the bucket wheel excavators in the conditions of Romanian open pit lignite mines*, 8th WSEAS International Conference on Simulation, Modelling And Optimization (SMO '08), Santander, Cantabria, Spain, September 23-25, 2008
- Kovacs, I., Andraş, I., Nan, M.S., Popescu, F.D., *Theoretical and experimental research regarding the determination of non-homogeneous materials mechanical cutting characteristics*, 8th WSEAS International Conference On Simulation, Modelling And Optimization (SMO '08) Santander, Cantabria, Spain, September 23-25, 2008
- Nan, M.S., *Parametrii procesului de excavare la excavatoarele cu rotor*, Editura Universitas, Petroșani, 2007
- Raaz, V., *Optimierung der maschinen- mid Verfahrenrechnerischen Parameter von Schaufelradbaggern für einen abbau von harteren Materialien im Tagebau*. Braunkohle in Europa: Innovationen für die Zukunft; 1.Internationale Konferenz, 29.März bis 1.April 2000. in Freiberg, Tagungsband
- Sümeği, I., *Külfejtési marótárcsás kotrógépek jövősző szerkezetének elméleti vizsgálata és fejlesztése*. Doktori értekezés, Miskolc Egyetem, 2002

# Study on improvement of a manufacturing system using Lean Manufacturing

Ana Gavriluță\*

*Manufacturing and Industrial Management Department, University of Pitești, Târgul din Vale Street No. 1, Pitești Romania*

---

## Abstract

Lean Manufacturing is today one of the most successful business strategies used to improve the organization competitiveness. It is based on the philosophy, concepts and instruments of Toyota Production System. Starting from this aspect, the main goal of this paper is to analyze and improve a production system using Lean Manufacturing tool, Value Stream Mapping – VSM. To achieve this target were followed the activities: analysis of the initial production flow and mapping of it, using VSM; identifying the improvement solutions and applying them in the studied production system. After the implementation of the improvement solutions, it was obtained an optimization of the manufacturing planning process and a considerable reduction of WIP.

*Keywords:* Lean Manufacturing, VSM, WIP

---

## 1. Introduction

Lean manufacturing is an approach to organizational management, which aims to improve the quality of work by reducing lost. This approach is extended to all aspect of activities – from design and manufacturing to the commercialization of products. The core principles were developed by the Japanese companies at the end of the ‘80s beginning of ‘90s. The Lean approach is to reduce actions that don’t bring added value to the product, in all his making cycle.

Garner, 2007 states that lean manufacturing approaches are adopted in an automotive parts manufacturer in order to remain competitive in an increasingly global market. The focus of lean manufacturing approach is on reducing the non-value added (NVA) waste that pollutes the flow of the product as it is being transformed in the value chain.

The usage of Lean tools depends on the nature of industry, the plant size and the technological capabilities of the country. Womack tell us in 2005 that most of the industries tend to implement 5S and other visual management tools. US industries use six-sigma somewhat heavily than the other countries. United States of America (USA) and Canadian industries use Value Stream Mapping (VSM) more than the small scale Indian industries.

## 2. Value stream mapping – lean manufacturing tools

Lean philosophy is based on the representation of the enterprise on the stream of flow of value for the client. The totality of actions passed by a product, with added value and without any, creates a flow. According to Lean, the tendency is to increase the speed of the flow of value, ensuring a continuity and uniformity by eliminating the loss caused by the activities with no added value.

To organize the map of flow and to identify where this must be improved, are used lean manufacturing tools. The Value Stream Map – VSM is the main tool to represent a flow of value, this allowing the analysis of present situation and the identification of loss that leads to delays in product making. Concluding there are two types of maps: the present one and the future one. The first reflects the model of the process at the start of the analysis and leads to its diagnosis (detection of loss), the second is the projection of the future situation – an optimized state. The second VSM is the base of the design of the new process.

---

\* Corresponding author. Tel.: +4-074-610-1580  
E-mail address: ana.gavriluta@upit.ro.

The value stream map is a schematic description of process by which a product passes from the supplier to the final client. The VSM reflects all the steps by which the product evolves, from the generation of ideas to development, to production and ending with the delivery to the client, after market and recycling, re-usage of materials and treatment of waste.

Because of the need to show the activities involved in making of a product, these are represented as the following symbols, fig.1.




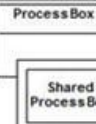


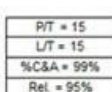


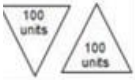










Symbols	Description	Symbols	Description	Symbols	Description
	Customer/Supplier Start or end point for material flow		Kaizen Blitz Area for improvement		External Shipment Shipments to or from suppliers
	Process Machine, operation or department through which material flows		Supermarket Small inventory for immediate production		FIFO First in, First out lane
	Data Box P/T = 15 L/T = 15 %C&A = 99% Rel. = 95%		Buffer Safety Stock		In Box Information Queues
	Inventory 100 units		Pull Symbols Replenish stock in supermarket		Internal Movement
	Work Cell		Kanban Card Replenish stock in supermarket		People, phones, operators, etc.
	Push Arrow		Load Leveling		
	NVA Delay 1 day		Go and See When there is a problem, go and see what's wrong.		Scheduling MRPI Scheduler

Fig. 1. VSM symbol

An important factor to create a correct VSM, is to make a very close to reality description of the actual situation, what is really happening on the field in the analyzed process. For that, the first step in building a VSM consists in the identification of product or of the family of products that would be the focus of the map. The next step is to establish the targets for the improvement of the process of product making, with a detailed description. A simple description, lacking in details of the process will lead to a wrong result, to loss of time and other resources.

The targets can be in the domain of safety, quality, supply chain, productivity, transport, flexibility, handling, ergonomics, cost, stock etc. To analyze this process, is recommended to establish a minimum of 1-2 objectives that allow the focus of team resources and a clear definition of priorities for the implementation of tasks. For this KPIs, will be defined the current situation and the targeted values.

After establishing the objectives, can be represented the flow of value starting from the client to the suppliers. The flow of materials is the most important part of logistic. It can be it, which can drive the improvement in the logistic processes and mainly in the improvement of the three main objectives of logistic: increase in quality level, reduction of the delay to make the products and reduction of costs.

In the literature, it is recommended to not split each analyzed product in its components, because this is mostly specific to other techniques of process mapping, as flow charting, that is a more correct tool for flow analysis with a more detailed level of representation. This flow map can have the following elements:

- The client at the end of process;
- The operations on a table format with details about: cycle time, change over time, number of people, uptime, available time, scrap rate, product diversities etc.;
- Stocks;
- Flow of materials;
- Assembly of components depending on the flow;
- The suppliers at the beginning of process.

After the flow of material is drawn, the next is represented on the map, the information flow. One of the details that differentiate a VSM from other lean charting instruments, is the inclusion of the flow of information. It contains details referring to: the way in which the clients order the product, frequency of orders, method and way of transfer of information back to the supplier, information referring to the method of panning and production programing etc.

The last step in making a VSM is to create the future flow of value in which are applied all the opportunities of improvement identified on the current state map (targeting a superior level of performance) and the development of the plan to transform the future map of value in a current state. In some cases, is better to develop an ideal map, which will highlight all the ways to improve by introducing all the possible action plan.

### 3. Description of the initial production system

In this paper is presented an example that intends to improve the performance of a manufacturing system. The system is split in two buildings. In the first section the products are machined and partially assembled. The sub-assembly is transferred to the second section, where are assembled on the final product. In the first building are two different production lines: the first is a manufacturing line and the second is an assembly of the sub-assembly. The storage area is in the first section. The link between the storage area and the manufacturing area is made through a tunnel. The supply of the line from section 1 is made with an electrical tractor. In fig.2 is represented the layout of this system with the areas of work and storage showed.

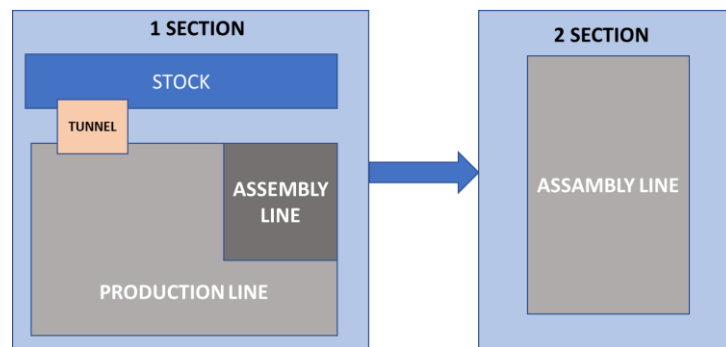


Fig. 2. Layout production system

The raw material is received by the logistic operator in the RM (raw material) truck station. From there the containers are moved with a forklift in the logistic warehouse, where are unloaded and stored on their designated place. In the storage area, the operator prepares the transport trolleys that will supply the workstations.

Now, the manufacturing line is supplied with components in the first operation, the launching point being in this workstation. The operator selects the manufacturing batch type and its quantity, loading the components on the entry of the line conveyor.

The transport between operations is done on a conveyer, using a transport adaptor (pallet) that allows the handing and positioning of these in the manufacturing centers, working in a closed loop. The assembly line is supplied in the first operation with machined components coming from the machining line. In the assembly line, the products are transported on similar adaptors (pallets). The last workstation of the assembly line is the unloading and production declaration. This is done with the help of an IT system, for each packaging the system printing labels that contain information as: reference, number of parts, weight of container etc. This label is attached to the container by the operator that works in this workstation.

The transport between the two lines is done manually. After the unloading of the parts from the manufacturing line and the production declaration, the transport trolleys are pushed manually by the operator to the assembly line, in a storage area for manufactured parts.

The operator that works in the first workstation of the assembly line takes the transport trolley and moves it at the entry of the assembly line. The surface designed for that is of 3.36 sq.m. The operator loads the assembly line manually, as seen in fig.3.

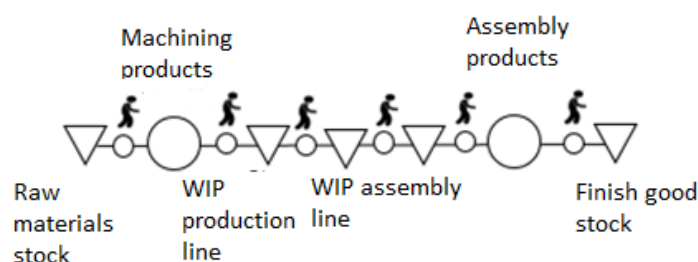


Fig. 3. Section 1

At the end of the assembly line, the operator places the sub-assemblies in the packaging. The operator pushes the full packaging in the storage area in the proximity of the assembly line end. From here, the packaging are taken by the logistic operator with the help of an electric tractor and are transported to the finished products warehouse. Here are around 3040 finished products that are stored on an area of 47.6 sq.m. From here the parts are transported to the second production section. The frequency of transport is of 2 hours.

To identify the areas with potential of improvement, the team made a VSM for the manufacturing system in its initial state, fig.4.

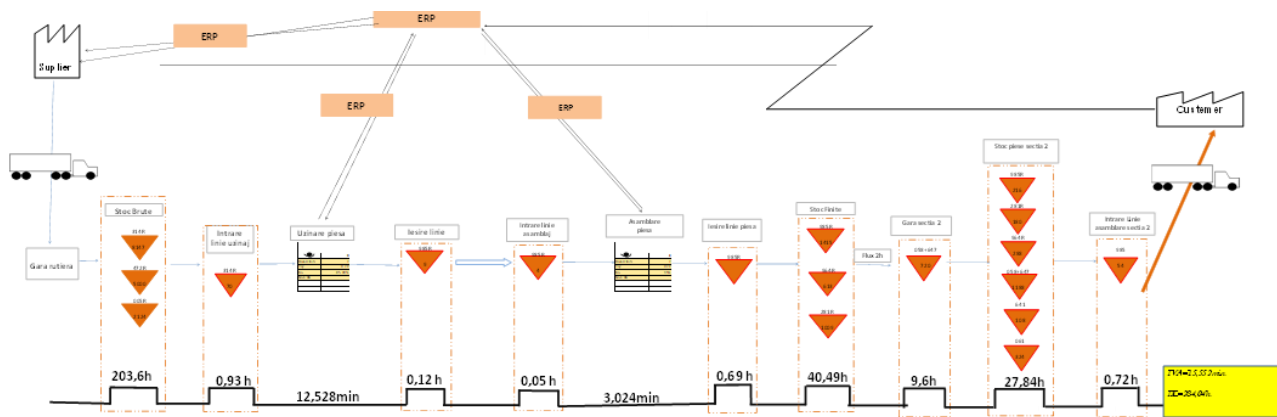


Fig. 4. VSM actual

After the analysis of the initial situation, the resulted KPIs chosen are represented in table 1.

Table 1. The initial results of the VSM analysis

KPI	Value
Number of handlings	18
Level of stock	21646 parts
Lead time	284,04 h
Storage area	278,6m <sup>2</sup>
Process efficiency: (TVA/TE)	0,0009%

Considering that the stock represents a loss, it was proposed to increase the frequency of transport between the two sections, in order to create a synchronous flow between section 1 and section 2 where the main assembly line is situated. In the current situation, the supply flow between the sections, is done in batches, reason that asks for a series of changes, as the reduction of handlings and the increase of transport flow.

#### 4. Amelioration of the production system

In order to make a direct flow of supply is needed that in the section 1, the manufacturing must be done synchronized with the assembly in section 2. In the initial situation, the operator does not have a fix number of packaging on the 2 hours flow, this differing depending on the request of the assembly line.

The reduction of stock level can be done by integrating an automated transport system between the manufacturing lines of section 1. For the automation of the transport between the manufacturing lines, are proposed two variants:

- Implementation of an AGV system;
- Implementation of conveyers system.

The first hypothesis includes the implementation of an AGV system including two conveyers and a robot, see fig.5. The use of AGV implies the design of a route for their circulation considering the crossing with other logistic flows and the space needed for maintenance access. The AGV is equipped with a support for transport pallets for the machined parts. The transfer of parts between the manufacturing line and the AGV is done by a robot at the end of line workstation and at the entry of the assembly line are two short conveyers that help the transfer between the AGV and the assembly line:

- A conveyor to unload the parts (pallets with parts);
- A conveyor to return the empty pallets.

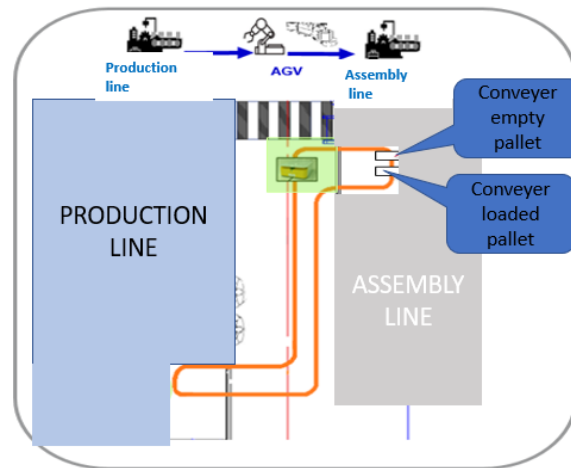


Fig. 5. Automation of transport using an AGV system

The second hypothesis: Implementation of a suspended conveyer with two elevators and a robot, fig.6. The loading of parts on the conveyer is done by a robot. At the operation of loading of the assembly line is designed an elevator system that takes the transfer pallet and transfers it to the upper conveyer system. The conveyer takes the pallet and transfers it to the assembly line. The upper conveyer has a return way for the transfer of empty pallets to the machining line where the robot makes the loading with the machined parts.

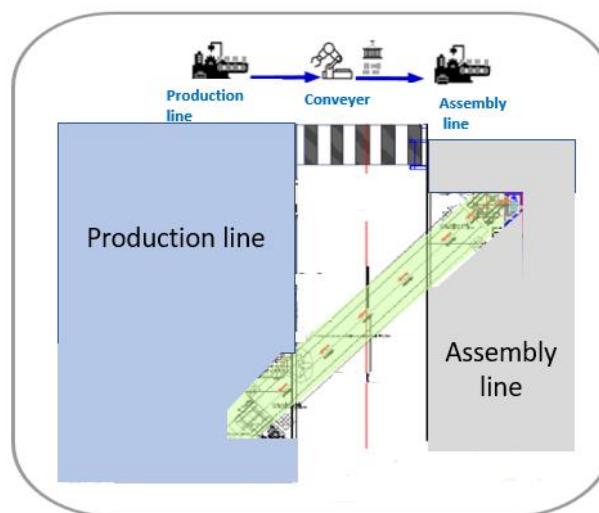


Fig. 6. Automation of transport using a conveyer system

Comparing the two hypothesis of improvement using the 4 KPI, are obtained the following values, show in table 2.

Table 2. Comparing between the transport systems hypothesis

KPI	Hypothesis 1	Hypothesis 2
Flexibility	+	-
Maintenance	+	-
Cost of implementation	55Keuro	300Keuro
Flow crossings	-	+

Using this KPI's it was chosen the improvement hypothesis 1, the automation of line supply with an AGV system. Also, the automation of transport allows to reduce the number of operators and the number of handlings of the overall industrial system.



## 5. Conclusions

Using the Lean Manufacturing tools, VSM, it was possible to identify the areas where manufacturing process can be improved aiming to synchronize the two manufacturing sections, leading to a reduction of stock level. The automation of supply process will be done by the implementation of an AGV system, considering that the implementation cost is lower and also the KPI's are better than the initial situation.

After the automation of the supply system, the following were reduced:

- The area of storage from section 1 and section 2, see fig.7;
- The level of stock from both sections, see fig.8;
- The number of handlings becomes 0, by eliminating the operators involved in the process.

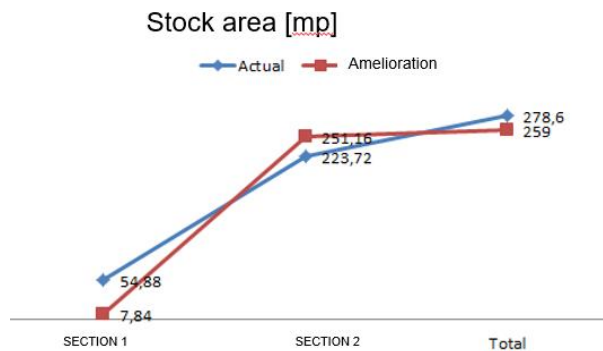


Fig. 7. Evolution of stock area

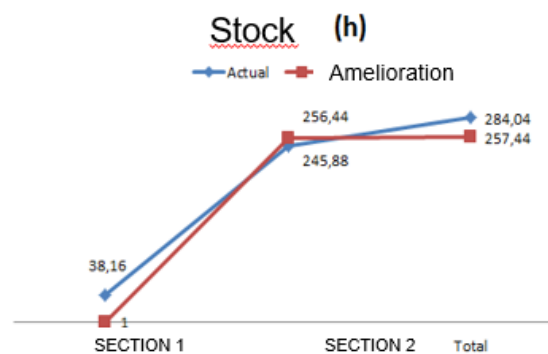


Fig. 8 Evolution of the stock

## Acknowledgements

This paper is developed in the context of the project “Development of a Lean Manufacturing research platform”, no. 07, financed by University of Pitesti.

## References

- Garner, W. & Goodyear, J., *Lean Operations*. Coventry: Faculty of Engineering & Computing, (2007).  
 Womack, J., *LEI State of Lean Survey Summary* [Online] (2005).

# Design of a learning platform for 5S method for using to improve a manufacturing system

Ana Gavriluță\*

*Manufacturing and Industrial Management Department, University of Pitești, Târgul din Vale Street No. 1, Pitești Romania*

---

## Abstract

For industry and science, the lean concept is a promising opportunity to realize a continuous quality while enhancing the effectiveness. Some industries, like the automobile industry, already reached a high lean status. The focus is on the methods of standardization and identification of problems, as 5S method. More the workplace is clean and organized, faster the problems are identified, because a clean working environment, is more predictive and a safer place. Starting from the principles of 5S method, the main objective of this paper is to develop a learning platform for this method, with the purpose to help increase the competences in Lean Manufacturing. The accuracy and usefulness of this platform is checked by using it in the improvement of a production system.

*Keywords:* 5S, factory learning, improvement, production

---

## 1. Introduction

Baena, 2017 tell us that the Learning Factory appear for the first time in an initiative of a group of universities from the United States in 1995 and since then was an official initiative for the education of engineers. Learning platforms constitute an indispensable tool for the deployment of online training courses. Not only do they provide significant benefits that have an impact on numerous areas of a company's presence, but they also showcase functional features which can take online training to the next level.

According to Veza, 2015, Lean Learning Factory appeared the first time in 2009 in the Faculty of Electric Engineering, Mechanical Engineering and Naval architecture, laboratory of industrial engineering of Split, Croatia. Its mission is to help bring the real-world into the classroom by giving practical experience for engineering students, to help transfer scientific research to industry through collaborative projects.

Lean Learning Factory was developed, firstly, to shorten the duration of implementation of this concept in an enterprise (usually the implementation of Lean Manufacturing concept in an enterprise is at least of 6 months). The second scope of this learning platform is to allow the teaching of Lean methods and tools, so the employees can apply them easily at their workplace.

Starting from this concept, in the laboratory of the University of Pitesti, it is developed a learning platform for the Lean Manufacturing concept. Part of this laboratory is the 5S platform that is developed and designed to ease the learning of this method.

## 2. 5S Methodology

5S Method was developed at the begging of the '80s by Hiroyuki Hirano in Japan and was first heard of as one of the techniques that enabled what was then termed "Just in Time Manufacturing".

An efficient and high quality work needs a clean environment, safety and rigor. The 5S principle, Seiri, Seiton, Seiso, Seiketsu, Shitsuke, allows the creation of a functional working environment, with simple, precise and efficient rules. The 5S is the foundation on which is it build the progress of Lean Manufacturing means and methods, acting as a stirring point in the management of change. In the same time, the 5S can be considered as basic rules of order, discipline, the starting kit for an improvement project.

---

\* Corresponding author. Tel.: +4-074-610-1580  
E-mail address: ana.gavriluta@upit.ro.

Starting from the statement “the loss is a potential gain”, any liberation of loss means a gain. Important to notice is that no real improvement of productivity and quality will persist in the presence of waste. Concluding, we can state that 5S represents a generic term, “a mnemonic mean to see principle of spirit”. The 5S represents the first 5 letters of Japanese origin. In table 1, are shown translations of these in French, literary and usual, English and Romanian.

Table 1. 5S structure

Japanese	French		English	Romanian
	literară	Usual		
Seiri	ranger	s'organiser	sorting out	a rândui
Seiton	ordre, arrangement	situer(les choses)	systematic, arrangement	ordine
Seiso	nettoyage	scintiller	spic and span	curat
Seiketsu	propre, net	standardiser	standardizing	standard
Shitsuke	education	suivi	self-discipline	urmărire

The first S – Sort focuses on eliminating unnecessary items in the workplace. Focuses on eliminating unnecessary items from the workplace. Categorize equipment, furniture, tool in your working place into the following 3 categories:

- Necessary
- Unnecessary
- May not necessary

This step will also help with the “just in case” attitude.

All the unnecessary objects will have a red label and these will be recycled or stored in a special area of the warehouse.

The second S – Set in order implies to arrange and reduce the useless search. The principle of this set of actions can be resumed as:

- To arrange the useful object in a functional manner
- To replace in the designated area the used tools
- To make accessories and supports, that allow a fast identification
- To define rules of arrangement

This last step means also to:

- Paint the surfaces so the dirt can be seen
- To visually mark the limits of work areas
- To highlight the tools positions on panoplies etc.

The third S - Scrub, Sweep, Straighten implies to clean, the workspace will be freed of all the dirt, dust, unwanted scrap, creating a healthy environment, safer for humans and machines. In this step are targeted mostly:

- Storage areas – warehouse, shelves, tools and equipment storage
- Equipment: machines, logistic equipment, elevators etc.
- Surroundings: corridors, windows, conference rooms, wardrobes, cabinets etc.

During the cleaning a series of observations must be made: broken parts, and measuring tools, loose nuts and bolts cracked housings, lubricant levels.

The forth S –Standardize - includes activities which establish a regular and continuous practice of maintaining tidiness, orderliness, and cleanliness. Make rules and procedures to promote a good work environment until the first three S become everybody second nature. Thus, the following kinds of: development of Standard Operational Procedures, display marking of safety signs, garbage segregation system following the infection prevention and control, waste management policy, color cording for linen system, zoning for storing/parking equipment.

The fifth S – Sustain – includes activities of revision of standards. It must be put in place a survey system, for the 5S, making sure that it will be continued. Periodically the limits of workstations and other specifications are revised in a process of continuum improvement, a Kaizen.

Shitsuke or the following, assumes also the involvement, meaning the auto evaluation, to promote a team spirit, to impose rules of behavior, to put in place a good communication, to valorize the obtained results etc. All must step is a big win. After a first successful implementation, it can be continued the process of sorting, amelioration of ranging (cleaning process) and other places not considered before.

### 3. Design the 5S platform

In order for the 5S method to be successful, the most important factor is the commitment, participation and involvement of everyone and strong visible support from top management. To ensure the success of implementation is needed that the all the employees of the enterprise know the 5S practices. Generally, 5S method can be performed with the help of specialists which obligated the employees to execute the improvements with 5S. The resistance to change of

the employees is most of the time caused but the lack of knowledge related to work improvement concepts. To easier spread the 5S methodology, in the Lean Learning Factory, it was build a learning platform Step-by-Step Implementation 5S, which encourages workers to become active in the implementation of this method. This platform which is the starting point of 5S: Step-by-Step Implementation, encourages workers to become actively involved in the application exercises.

To build the 5S platform were used aluminum profile Lean Cube. The Lean Cube it is made as the model of Lean CUBE on site [www.Leanproducts.eu](http://www.Leanproducts.eu). The aluminum profile Lean 5S CUBE is a display system combine display boards with the concept of LEAN displays offering a compact solution for teaching, information display, and visual management and have the next specifications:

- writable with every type of marker
- magnetic surface
- erasable surface
- base on wheels
- Structure is 650x650x2000 mm, see Fig. 1

The first facet of the cube is dedicated to learning the principles of the first S. This contains:

- The definition of first S
- The red list – all the unused objects
- The yellow list – all the objects that could be useful or we are not sure we will could find them any use
- The green list – all the objects that are in use
- The red labels – that will be placed on all the objects from the red list
- The register for red labels – in which are registered all that is happening with the labeled objects (to be recycled/ stored in another area etc.), see fig.2.



Fig. 1. Aluminum Lean Platform



Fig. 2. The 1S platform

To the second S is presented on the second facet of the Lean Cube. This side teaches us how to use the 5S tools to help for the cleaning:

- The definition of the second S
- How to range the objects based on “Can see, Can take-out, Can return” Philosophy
- 5S color coding
- How to label the objects so we can easily identify them
- How to mark the areas of work, see fig. 3a.

The next facet of the Lean “cube” teaches us how to clean, how to identify what are the causes of apparition of dirt and how can we standardize. This contains:

- The definition for 3S and 4S
- Cleaning activities methodology
- Total equipment management
- The standardization methodology, see fig. 3b

The last facet of the “cube” helps to learn how to make a 5S audit and how to maintain all that we obtained on the first 4S, therefore it contains:

- The definition of the 5th S;
- 5S audit check list;
- 5S audit summary sheet;
- Improvement Opportunity cards and blue 5S Achievement cards, see Fig.3c.

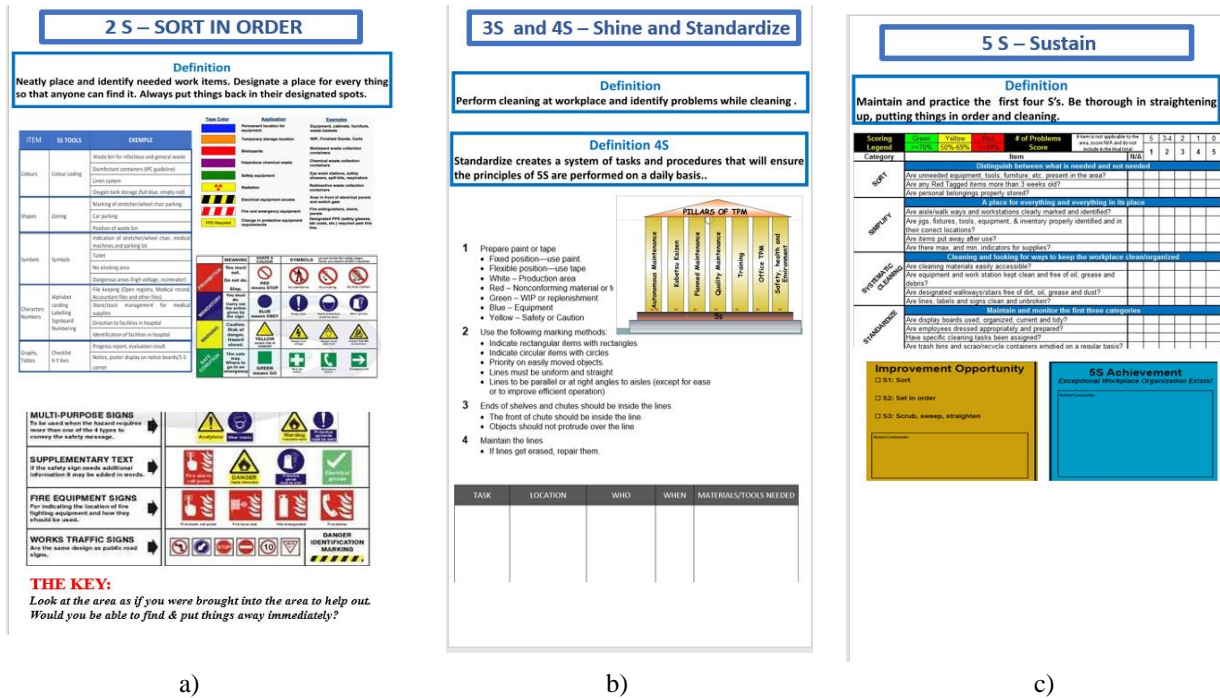


Fig. 3. 5s Platform

## 4. Conclusions

This paper presents a holistic approach to competence developments of 5s in learning factory. Among primary activities the principles of the 5S method can also be found in support activities of a company and have established the approach of Lean method. 5S Platform represents an outstanding possibility to implement active learning methods and to improve learning environments. With the help of this we can increase the classes of competences which are necessary for future employees in the industry.

## Acknowledgements

This paper is developed in the context of the project “Development of a Lean Manufacturing research platform”, no. 07, financed by University of Pitesti.

## References

- Baenaa, F., Guarina, A., Moraa, J., Sauzab, J., Retat ,S., *Learning Factory: The Path to Industry 4.0*. Procedia Manufacturing, pp. 73-80 (2017).
- Veza, I., Gjeldum, N, Mladineo, M., *Lean Learning Factory at FEBS – Univesity of Split*, Procedia CIRP 32, pp. 132-137, (2015).

# Analysis of micro-profile machining of the non-planar surfaces of injection molds for polymeric composites

Daniel Șerban<sup>a,\*</sup>, Constantin Gheorghe Opran<sup>a</sup>

<sup>a</sup>University POLITEHNICA of Bucharest, 313 Splaiul Independentei, 060042, Bucharest, Romania

---

## Abstract

Plastics are one of the 21st Century materials with an innovative development to meet the society's targets: resource efficiency, zero-energy buildings, saving water, reducing the gas emissions, waste as a resource, recycling closing the loop of “Circular Economy”, to name only few. Injection molding of polymeric composites products is one of the most used processes with low cost, good accuracy and high productivity. Mold surfaces are influencing the product quality, the ejection, the flow, and the aesthetic of the part. In this paper we analyze the micro profiling of the non-planar surfaces of an injection mold for a scaled model of a 15th Century stone church from Hațeg County, Romania. We present a study of milling the micro-profiles (details of bricks and stone in the range of 100 to 500  $\mu\text{m}$ ) directly into the mold cavities and milling the electrodes followed by electrical discharge machining. For the milling process two strategies were compared: milling the 3-dimension model and milling/engraving the vector pattern projected on the non-planar surfaces. The experiments consisted in building an aluminum mold and evidenced a good replication by injection molding the model parts in a composite of recycled polystyrene matrix, results being compared with the flow simulation.

Keywords: Injection molding; micro-profile; polymeric composites;

---

## 1. Introduction

This paper presents two methods for micro-profiling the injection mold surfaces of a scaled model of 15<sup>th</sup> century stone church. Estimating details in 3 dimensions for architecture from imagery presented interest to researchers and were proposed methods and software for obtaining surfaces patterns. Modeling in 3 dimensions is not only a creative activity but also a cognitive one as digital models which allow simulation, visualization. Modeling in 3 dimensions helps the manufacture of complex polymer composites injection moulds and to analyze the flow simulation. Micro-profile finishing the surfaces requires a lot of labor for available technologies: chemical etching, laser ablation, milling or electrical discharge machining. With the goal to find low-cost solutions, in our study we compare a method of combining 2D vector extraction from image of a brick and to 3D pattern onto mold surface with machining by generating the tool path on the surface projected vectors.

## 2. Related works

There are studies regarding the reconstruction of historical buildings and suggested methods for 3D digital modeling (Spallone, 2007), parsing architecture within plan drawings (Willis, 2009), who suggests a methodology in 7 steps: digitize the manuscript, pre-process the image, estimate a skeleton shape, vectorize, estimate a shape, each pixel in the binary image is assigned a semantic label and construct the 3D model; estimating details of Gothic architecture from imagery versus other methods which integrate the 3D measurements with texture data (Willis, 2010), or five-axis tool path generation for 3D curves created by projection on B-spline surfaces (Can and Unuvar, 2010), 3D reconstruction models for 3D engraving from 2D images by hybrid reverse engineering consisting in transforming an image to gray-scale and reducing the noise followed by cloud points extraction techniques for interactive design of brickworks by integrating two computational platforms – based on image and on parametric modeling (Afsari et al, 2014).

---

\* Corresponding author. Tel.: +40-021-242-0514; fax: +40-021-233-0581.

E-mail address: dserban@ddplast.ro

### 3. Experiments

We choosed as model a 15<sup>th</sup> Century stone church from Hațeg County, Romania. This paper analyses the micro machining path generation of the 3D surfaces of an aluminum EN 7075 injection mould for a church scaled model, details of bricks and stone. One method consists in extracting vectors from a picture and project the 2D sketch onto the 3D surface and second method consists in 3D modeling the solid and milling with a pocket strategy followed by a parallel finishing.

Table 1. List of operations and time consumed for completion the micro profiling of mould surfaces

Operation	Method A [Hours]	Method B [Hours]
	North Wall	South Wall
Design CAD (3D modeling) the walls	1	1
Modeling The Mould Cavities	1	1
Extract vectors from picture, 2D sketch	1/2	-
Modeling 3D detail of wall texture	-	2
Milling the cavities ( no texture)	3	3
Modeling and milling the electrode for North Wall	2	-
Micro Milling the electrode	1	-
Electrical Discharge Machining	1/2	-
Micro Milling The South Wall Surface	-	1
Total [hours]	9	8

For vector extraction was used an image of the North Wall apse and a raster resolution of 96 DPI (dots per inch), on a Stentiford Algorithm (Kumar and Teja, 2014). The vector extraction was exported in dxf format (Drawing Interchange Format) and then imported as a 2D sketch into the CAD/CAM software as presented in Fig.1 (b). The sketch was used to micro profile the electrode for the North mould cavity as a projection on the 3D surface tool paths. Then we investigated the milling and electrical discharge technologies of micro profiling the 3D surfaces and the replication by injection molding of a polymeric composite made of a high impact polystyrene matrix with ceramic powder 5%.

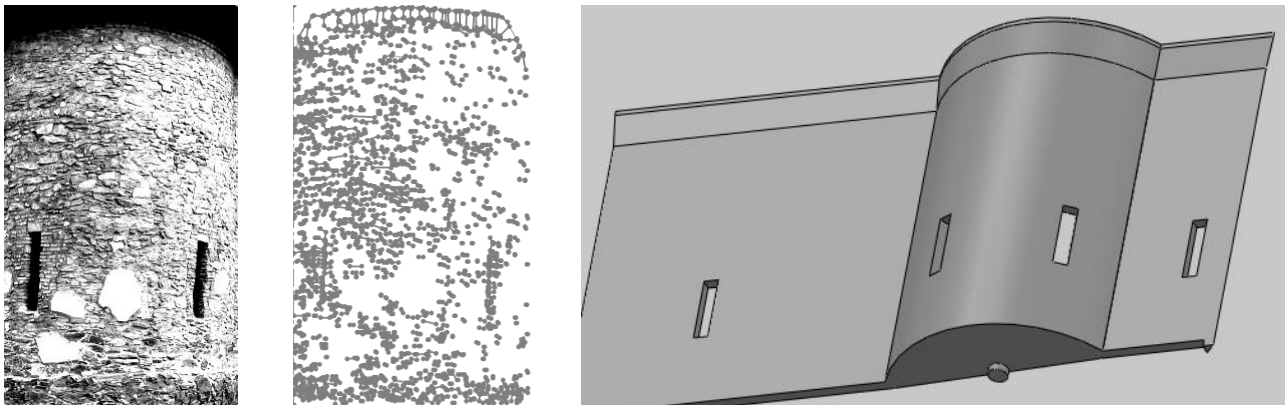


Fig. 1. (a) Church North Wall (Apse detail) ; (b) Vectors extraction; (c) 3D Model of Church replica 1:200 scale;

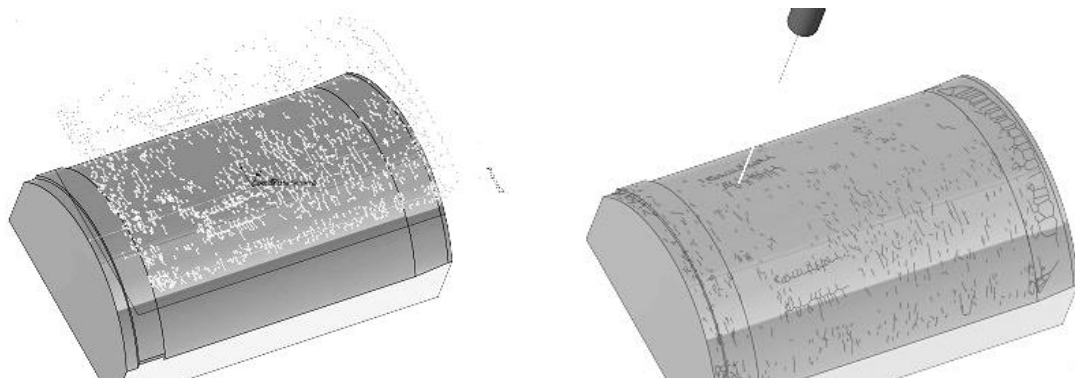


Fig. 2. (a) 2D sketch from picture extracted vectors ; (b) 3D Electrode with projected tool path on surface



Micro milling of the copper electrode and of the aluminum cavity was worked with a 0.1 mm pin point carbide tool on a milling machine with direct measurement system and a spindle of maximum 24.000 rpm. We used a projection a 2D sketch on a 3D surface strategy for micro profiling the electrode and a parallel technology for direct carving the South Wall apse cavity.

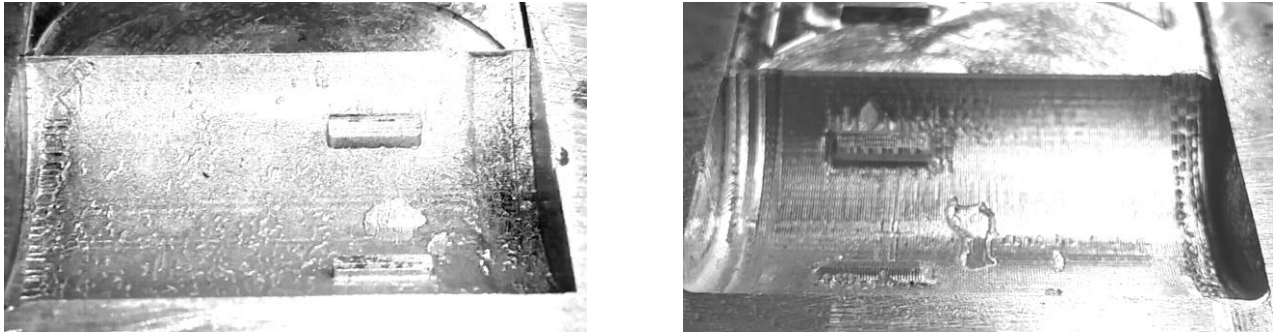


Fig. 3. (a) Electrical Discharge Machining North Wall Cavity; (b) Micro Profile Milling South Wall cavity;

Injection molding was performed on 1.000 KN clamping force machine with a 40 mm screw diameter. The pressure into the cavity was measured with a DME analog controller and a pressure sensor model 405C. For a good filling we adopted a strategy in two steps: finding out the injection pressure and the stroke to fill 95% the cavities and only second to pack to 100% the parts. On Table 2 we present a comparison between the flow simulation and measured ones of injection pressure and injection time.

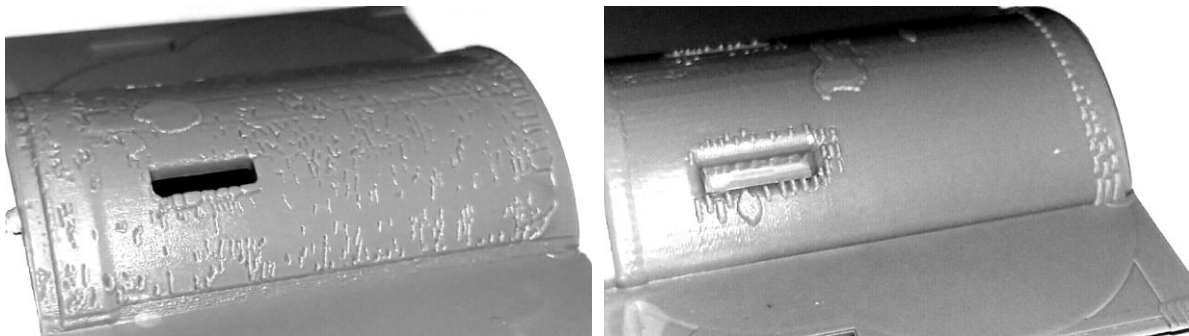


Fig. 4. (a) Detail of North Wall Apse Injection Moulding ; (b) Detail of South Wall Apse;

1. Table 2. Injection Moulding Parameters Comparison

Parameter	Measured Value	Flow Simulation Value
<i>Maximum Cavity Injection Pressure</i>	12.5 MPa	11.7 Mpa
<i>Filling Injection Time</i>	1.1 s	1.3 s

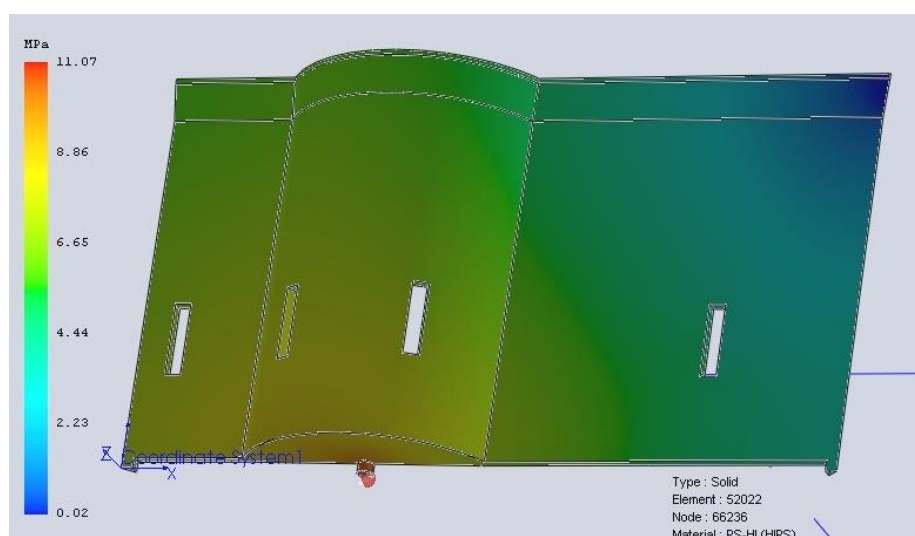


Fig. 4. Flow simulation of North Wall, Maximum Injection Pressure 11.07 MPa;

#### 4. Conclusions

Vector extraction from image could offer the advantage of a reliable solution saving modeling time for replication of real models into products. It is a good method to obtain patterns for texturing, micro profiling injection moulds surfaces for polymeric composites. The experiments evidenced a good replication of the surface of the polymeric composite for both methods in machining the micro profiled cavities. 3D modeling helps designing complex assemblies, helps visualization and simulation.

#### References

- Afsari, K., Gentry, R., Swarts, M.E., *Integrated Generative Technique for Interactive Design of Brickworks*, Conference Paper, Itcon Vol. 19, pg. 225-247, (2014)
- Can, A., Unuvar, A., *Five-axis tool path generation for 3D curves created by projection on B-spline surfaces*, Int J Adv Manuf Technol (2010) 49:1047-1057, DOI:10.1007/s00170-009-2459-z, (2009)
- Kumar, A., Teja, V., R., *Edge Detection Based on Otsu Method and Stentiford Algorithm*, IJERT, ISSN: 2278-0181, Vol. 3 Issue 11, November-2014, (2014)
- Spallone, R., *3D Digital Modelling as a method for the reconstruction of the historical image of the city: the case of piazza Bodoni in Turin (Italy) at the end of nineteenth century*, XXI International CIPA Symposium, 2007, Athens.
- Willis, A., Galor, K., *Parsing Architecture within Plan Drawings with Application to Medieval Castles and Fortresses*, The 10<sup>th</sup> International Symposium on Virtual Reality, Archaeology and Cultural Heritage VAST, (2009)
- Willis, A., Galor, K., Sanders, D., *Estimating Gothic Façade Architecture from Imagery*, Conference Paper, DOI:10.1109/CVPRW2010.5543519, (2010)

# Flow Analysis of the Pressure Distribution in the Experimental Chamber of the Differential Pumping

Pavla Hlavatá<sup>a</sup>, Jiří Maxa<sup>a\*</sup>

<sup>a</sup> Brno University of Technology, Technická 10, Brno 61600, Czech Republic

## Abstract

The paper deals with the effect of the critical flow, which is reached during pumping of the differential pumping chamber of the Environmental Scanning Electron Microscope (ESEM). The study compares the state of the flow in the area of pumped chamber at pressure ratio on the apertures when the critical flow occurs and its advantages in design of the chambers versus the flow without the clogging the nozzle. The problem was solved using the finite volume method by the Ansys Fluent system.

**Keywords:** Differentially pumped chamber; ESEM; Ansys Fluent; The finite volume method; SolidWorks

## 1. Introduction

The article is based on a study of Dr. Danilatos, 2012, which deals with the pumping of the differential pumped chamber in the environmental scanning electron microscope using the Monte Carlo statistic method. Based on these articles, a comparative study by Maxa, 2016 was produced, where comparable results were obtained by mechanism of continuum using the Ansys Fluent system which use the finite volume method, see Fig 1. and Maxa 2011 and 2012.

On this type of differentially pumped chamber, the analysis was made which monitor the impact of the shape of differentially pumped chamber on the flow path behind the aperture PLA 1 see Neděla 2010. This flow is interesting because of the critical flow created behind the aperture PLA 1, see Vyroubal 2013.

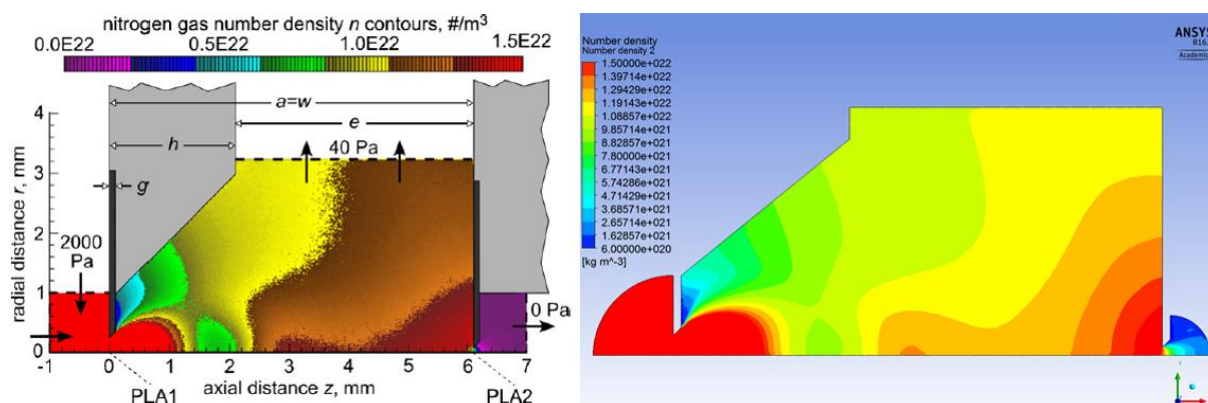


Fig. 1. Comparison of the analysis results obtained using Monte Carlo method and mechanism of continuum

On Institute of Scientific Instruments of Czech Academy of Sciences and Faculty of Electrical Engineering and Communication Technologies is preparing to base the theoretical studies with the experimental measurement of given physical conditions: supersonic flow in low pressures in the borderland of mechanism of continuum as a part of the Environmental scanning electron microscope parts development, see Neděla 2015, 2016, 2018.

\* Corresponding author. Tel.: +420 54114 6129; fax: +420 54114 6147.

E-mail address: maxa@feec.vutbr.cz.

## 2. Experimental chamber

Prepared experimental chamber is constructed as a multicellular for the full scale of physical measurements. For example:

- Flow velocity above the aperture
- Pressure running in the flow axis above the aperture
- Pressure on the nozzle walls
- Pressure and temperature on chamber walls
- Optical method uses
- And etc.

The picture of the preparing experimental chamber is in the Fig.2

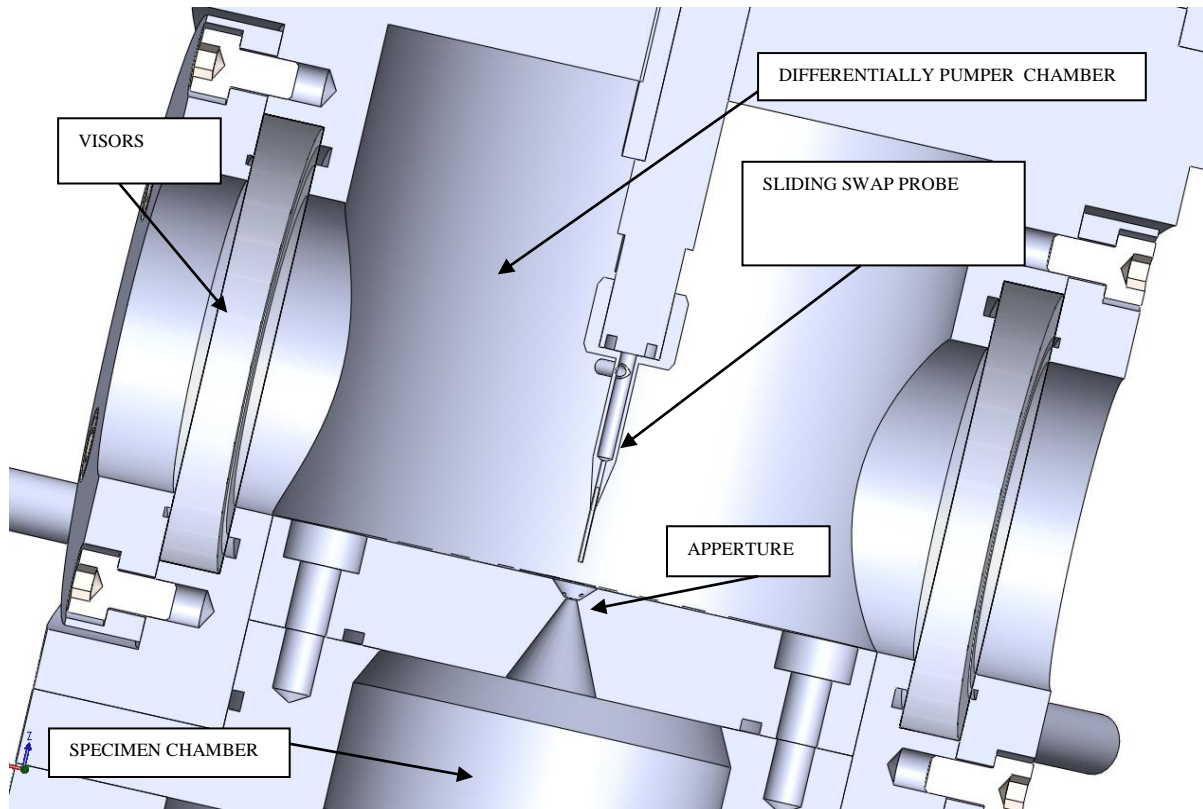


Fig. 2. Experimental chamber

Before the construction of given chamber took place many types of simulations to obtain presumed physics results, which will be compared with next experimental measurement. The construction of the chamber also came out from the series of mathematical- physics analysis.

In the Fig. 3 is pictured the 2D axisymmetric model of given chamber for the analysis in the Ansys Fluent system with the boundary conditions: in the specimen chamber is the area of 2000 Pa. The pressure is pumped through the aperture with the diameter of 0.5 mm to differentially pumped chamber and from here with appropriate feat to have 40 Pa in the differentially pumped chamber. It is about usual conditions in the environmental electron microscope.

Due to markedly different pressures in both sides of the aperture, the critical flow creates behind the aperture.

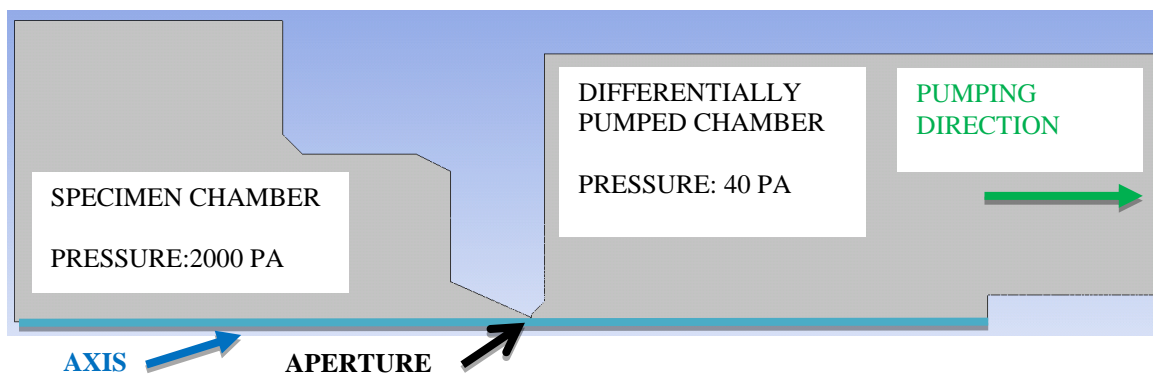


Fig. 3. Axisymmetric shape of the experimental chamber for simulations

### 3. Ansys Fluent system

To solve this problem, the Ansys Fluent was used, which uses the mechanism of continuum solving the equations by finite volume method. Due to the supersonic flow, the solver setting was chosen as Density based with the second order discretization. Density - Based solver solves the equations for momentum, continuum and energy at the same time, equations for other scalar quantities are solved separated after that. Also, in this case is the condition to determine number of iteration cycles to meet the convergence requirement. The Density - Based method solver offers two types of equation linearization method, explicit and implicit method [12]. In explicit method are the unknown values, in every cell, calculated using relationships which contain just existed values, known from the previous iteration. In this method can occur problems with numerical stability. In implicit method are the unknown values determined from existed and unknown values in near cells [12]. In our case, due to the difficulty of convergence, the implicit method was used.

### 4. Results

We evaluated the running of velocity, pressure and temperature in chosen lines see fig. 4 and also it was evaluated the total layout of given quantities in the chamber.

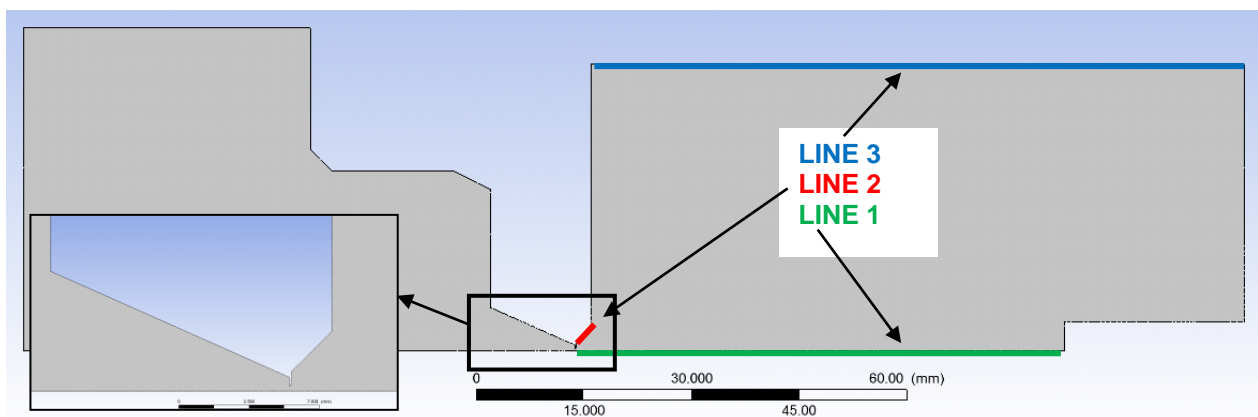


Fig. 4. Monitored paths

From the results comes out that above the aperture according to the pressure gradient occur the supersonic flow, when the velocity in the distance of 1.2 mm achieves almost values of 2 Mach. In this area the big pressure gradient occurs up to value of 16 Pa, see Fig.5 and 6. In the area, where the flow velocity drops below the velocity of 1 Mach, the pressure raises, and the shock wave is created, as is obvious in Fig 6 b.

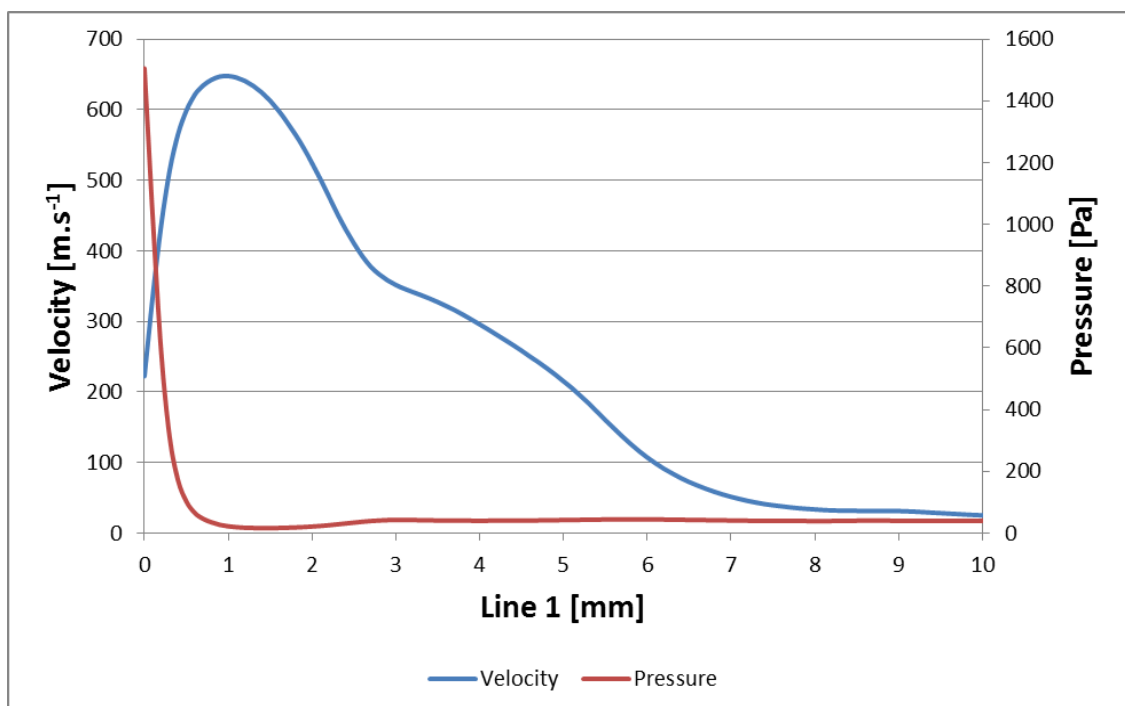


Fig. 5. Velocity and pressure running on line 1.



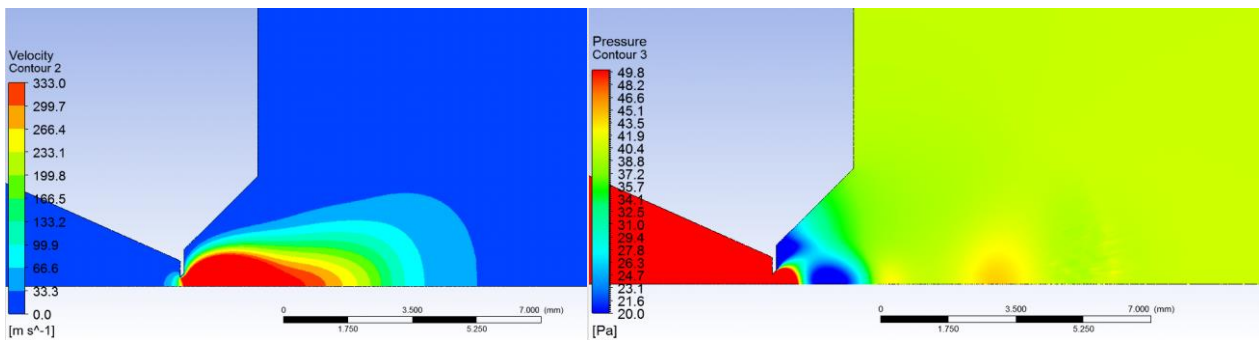


Fig. 6. (a) Velocity layout above the aperture – line 1; (b) Pressure layout above the aperture – line 1

In the Fig. 7 is pictured the temperature running with the dependence on the distance from the aperture on the line 1. The temperature behind the aperture drops up to value of  $-183\text{ }^{\circ}\text{C}$ . The reason of the quick temperature drop of the gas is supersonic flow state. After the minimum achievement because of the velocity drop below the value of 1 Mach, the temperature starts to rise and stabilize on the temperature of the differentially pumped chamber. The temperature will be scanned also from the walls of the differentially pumped chamber for the evaluation of the temperature layout in given chamber during its pumping- see line 3. The temperature running is evaluated in Fig. 8.

Another criterion will be pressure scanning using differentially pressure probes from the aperture walls – see line 2. Its running according to the mathematical – physics analysis is pictured in Fig. 9.

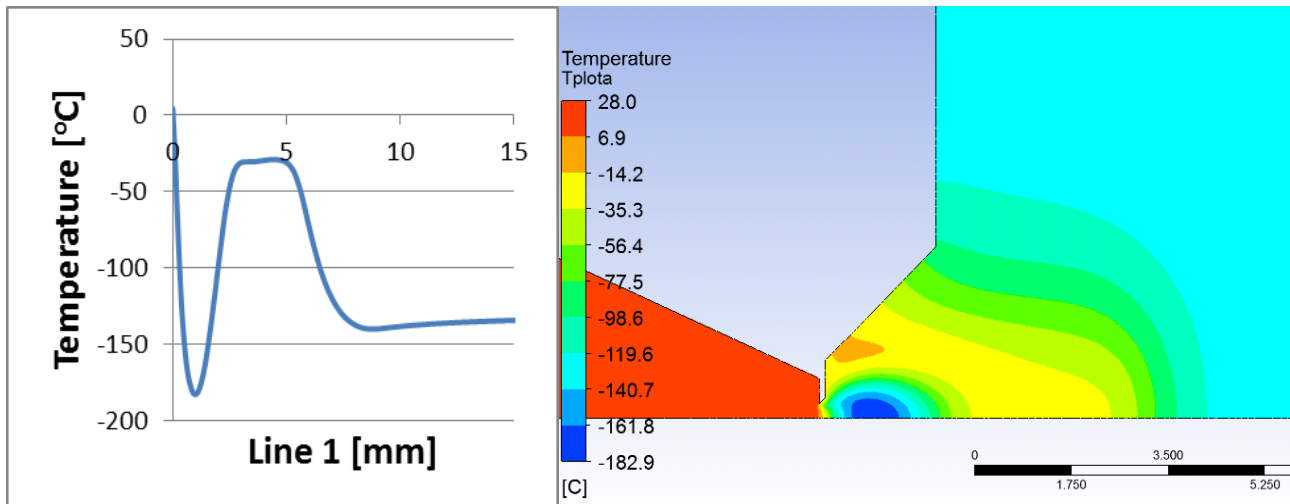


Fig. 7. Temperature layout above the aperture – line 1

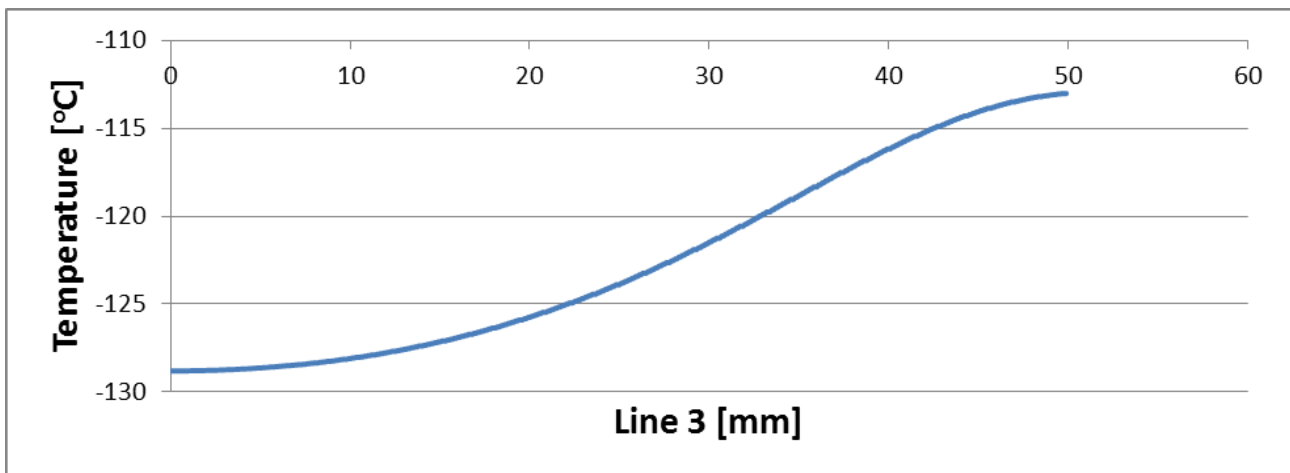


Fig. 8. Temperature layout on the chamber walls – line 3

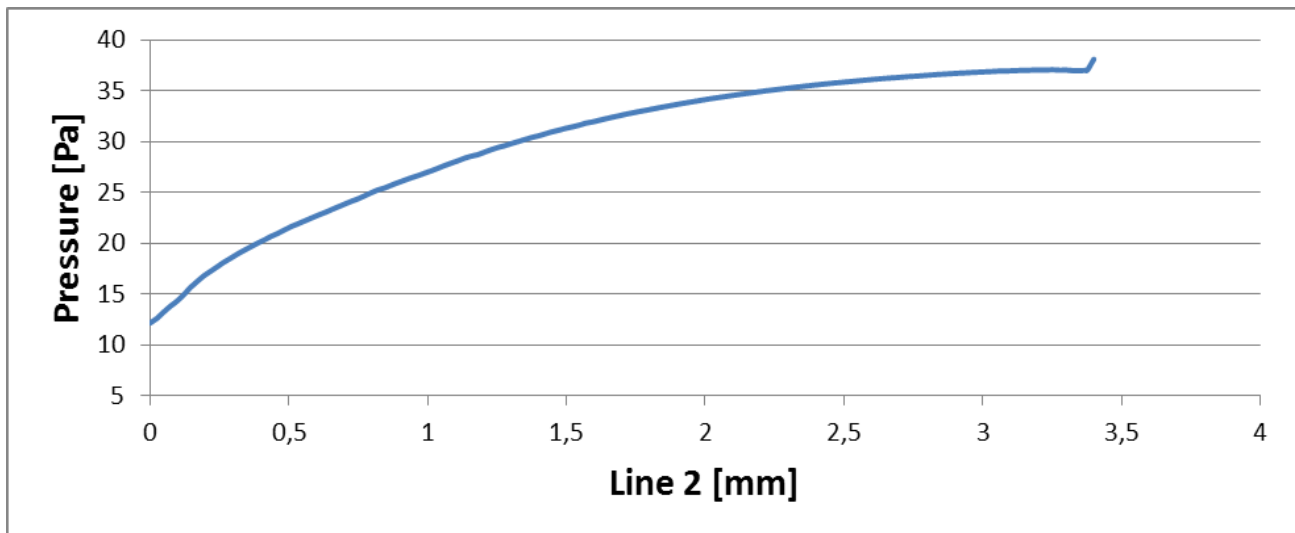


Fig. 9. Pressure layout on oblique aperture wall – line 2

## 5. Conclusion

It was made mathematical – physics analysis of the suggested experimental chamber. From the results comes out that for corresponding measurement is necessary to provide temperature probes able to capture the temperature up to  $-183\text{ }^{\circ}\text{C}$ , also the pressure probe used for capturing of the total and static pressure on the line 1 able to work in cryogen regime, where the very low temperatures are expected.

For pressure capturing from the conic aperture walls – see line 2 and Fig. 9 – is necessary for corresponding measurement to provide probes with the measurement error up to 1 Pa, because on this path will be expected, according to the analysis, the difference between the measured places approx. 5 Pa.

## Acknowledgements

This research has been carried out in the Centre for Research and Utilization of Renewable Energy (CVVOZE). Authors gratefully acknowledge the financial support from the Ministry of Education, Youth and Sports of the Czech Republic under NPU I programme (project No. LO1210) and BUT specific research programme (project No. FEKT-S-17-4595).

## References

- Danilatos, GD., *Velocity and ejector-jet assisted differential pumping: Novel design stages for environmental SEM*. *Micron*, vol. 43, no. 5, p. 600-611, (2012).
- Maxa, J., Bílek, M., Hlavatá, P., Vyroubal, P., Leplová, K., *Comparisons Using Methods of Continuum Mechanics and Monte Carlo at Differentially Pumped Chamber*. *Advances in Military Technology*, vol. 11, no. 2, p. 143-150. ISSN: 1802-2308. (2016).
- Maxa, J., Neděla, V., *The Impact of Critical Flow on the Primary Electron Beam Passage through Differentially Pumped Chamber*. *Advances in Military Technology*, , vol. 6, no. 1, p. 39-46. ISSN 1802-2308, (2011).
- Maxa, J., Neděla, V., Jiráček, J., Vyroubal, P., Hladká, K., *Analysis of gas flow in a secondary electron scintillation detector for ESEM with a new system of pressure limiting apertures*. *Advances in Military Technology*, vol. 7, no.2, p.39-44, (2012).
- Neděla, V., *Controlled dehydration of a biological sample using an alternative form of environmental SEM*. *Journal of Microscopy*. **237** (1), p. 7-11. ISSN 0022-2720. (2010).
- Vyroubal, P., Maxa, J., Neděla, V., Jiráček, J., Hladká, K., *Apertures with Laval Nozzle and Circular Orifice in Secondary Electron Detector for Environmental Scanning Electron Microscope*, *Advances in Military Technology*, vol. 8, no. 1, p. 59-69, (2013).



- Neděla, V., Konvalina, I., Oral, M., Hudec, J., *The Simulation of Energy Distribution of Electrons Detected by Segmental Ionization Detector in High Pressure Conditions of ESEM. Microscopy and Microanalysis*, p. 264-269.
- Neděla, V., Hřib, J., Havel, L., Hudec, J., Runštuk, J., *Imaging of Norway spruce early somatic embryos with the ESEM, Cryo-SEM and laser scanning microscope. Micron*, no. **84**, p. 67-71. ISSN 0968-4328, (2016).
- Neděla, V., Tihlaříková, E., Runštuk, J., Hudec, J., *High-efficiency detector of secondary and backscattered electrons for low-dose imaging in the ESEM. Ultramicroscopy*, p. 1-11. ISSN 0304-3991, (2018).

## Frangible Coupling a Safety Element in Airports' Traffic

Iosif Dumitrescu <sup>a</sup>, Răzvan Bogdan Itu <sup>a\*</sup>

<sup>a</sup>University of Petroșani, University Street, No 20, Petroșani 332006, Romania

---

### Abstract

Any source of light from an airport area which is situated above the level of the runway must have a breaking section, which should give in the case of a collision with an airplane or any other vehicle. This breaking section is assured by a frangible coupling, which is an replacable part in the construction of the support. In this paper, we present the constructive solution of a frangible aluminium coupling, which must offer a breaking section at a height of maximum 38 milimetres above the level of the runway, for a height of the signal light of maximum 360 mm. The breaking section of the frangible coupling must resist at the air speeds behind a large plane, speeds that can go up to 480 km/h, and give in at a bending moment which is between 204 and 678 J. This frangible coupling was made by the firm ElectroMax Petroșani and was tested in the Strength of materials laboratory from the University of Petroșani.

*Keywords:* frangible support, signal light, panel, airport.

---

### 1. Introduction

Romanian civil aeronautical reglmentation RACR - AD – PETA ”The design and technical exploitation of airfields”, edition 2/2015 from 11.05.2015, chapter 5, defines signal lights as needing to be frangible. Those that are situated near a runway must be low enough to ensure the existence of the safety distance for the screw or for the propellers of the reaction engines. Sometimes anchors or chains are used, in order to avoid for the signal lights that are torn from their support to be carried away by the blow of the engines or by the wind.

The counselling material regarding the frangibility of signal lights is included in The Manual for the Designing of Airfields (ICAO Doc.9157), Part 6. The materials and configurations for the frangible structures must be appropriate for the desired use and must realize a structure as light as possible. The structures can be made of metallic or nonmetallic materials which are not affected by climatic conditions in the outdoors. The materials selected in order to fulfill the frangibility requirements must be strong, light and must have a reduced hardness module. Minimum weight is important, in order to ensure that the lowest quantity of energy is consumed in order to accelerate the signal lights' mass at the speed of the plane that hits it (The reference of the manual for designing the airfield ICAO, part 6, section 4.7.1.).

Nonmetallic materials can be especially conceived in order to offer excellent frangibility characteristics. However, their structural behavior can be difficult to analyze, because of the incertitude regarding their elasticity module or material isotropy. All the materials must be able to resist or be protected against climatic effects, including: temperature fluctuations, solar radiations, vibrations, bad weather (salt spray, wind, relative humidity) and corrosion (due to rain, snow, ice, sand, dirt or degradation materials) which are usually found in the air.

AC 150/5345 – 46 D regarding the plans of runway illumination offers guidance for light bodies situated along the runway. L-804 the elevated light bodies must have a frangibility point which is not larger than 1.5 inches (38 mm) above the runway.

For these devices, frangibility is attained by reducing the exterior diameter of the transversal section or by working on some holes or on other elements that reduce the effective resistance of the coupling at the height of 38 mm above the fixing foundation of the signal light (Fig. 1). Frangible coupling must work at temperatures of between -25° Celsius and +55° Celsius, at humidity between 0-100% and withstand wind speeds of up to 480 km/h. The coupling must break at a bending point situated between 204 and 678 J (Nm).

---

\* Corresponding author. Tel.: 040727863426  
E-mail address: raz.van4u@yahoo.com



Fig. 1. Examples of frangible couplings

## 2. Establishing a constructive solution for the frangible signal light support

In figure 2, we show the general design of the signal light, which is made up of: 1 – signal light APP AL 008 02 WH; 2 – bracelet; 3 – M6x25 screw; 4 – aluminium tube  $\Phi 40 \times 5$ ; 5 – frangible coupling G2<sup>''</sup>; 6 – M6x16 screw; 7 – square base of 140x140.

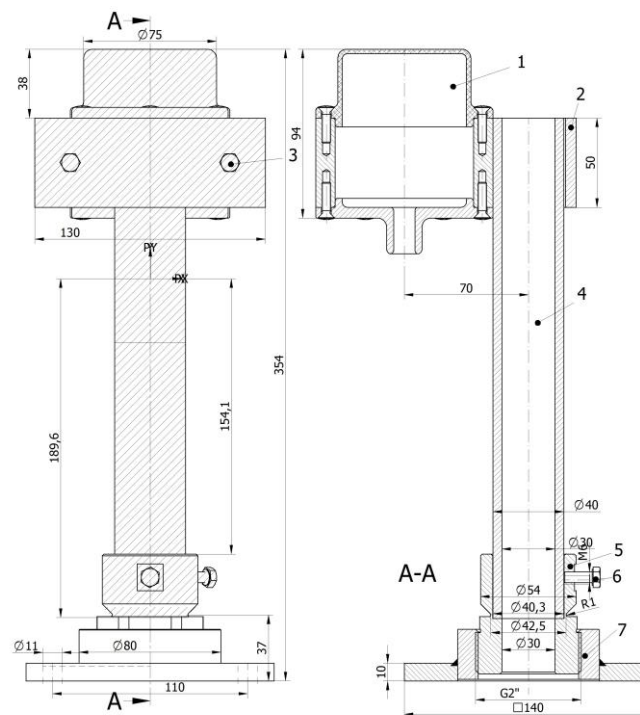


Fig. 2. The constructive solution for the support of the signal light APP AL 008 02 WH.

Based on these solutions, we drew a summary of calculus with the help of the software MathCAD, which allowed the checking of the bending of the tube in the area of its fixing in the coupling and of the breaking section of the frangible coupling for wind intensities situated between 240 and 480 km/h for an aluminium tube of  $\Phi 35 \times 2$  mm and  $\Phi 40 \times 5$  mm, which are shown in figure 3.a., curves 1 and 2. Also, we represented the bending tension in the tube of  $\Phi 35 \times 2$  mm, for the minimum bending moment of 204 J, curve 3, and for the maximum value of 678 J, curve 6. The admissible tension for the tube made out of aluminium alloy EN WA 6082/ SR EN 755-2 was taken as equal to the flowing limit, which is of 250N/square mm, curve 5. We can observe that the bending tension of 432,8 N/mm<sup>2</sup>, given by the maximum moment, curve 6, is much higher than the admissible tension, which imposes the choosing of the tube  $\Phi 40 \times 5$  mm. Curve 5 represents the tension of maximum bending, of 153,05 N/square mm, from the tube  $\Phi 40 \times 5$  mm, which is lower than the admissible tension.

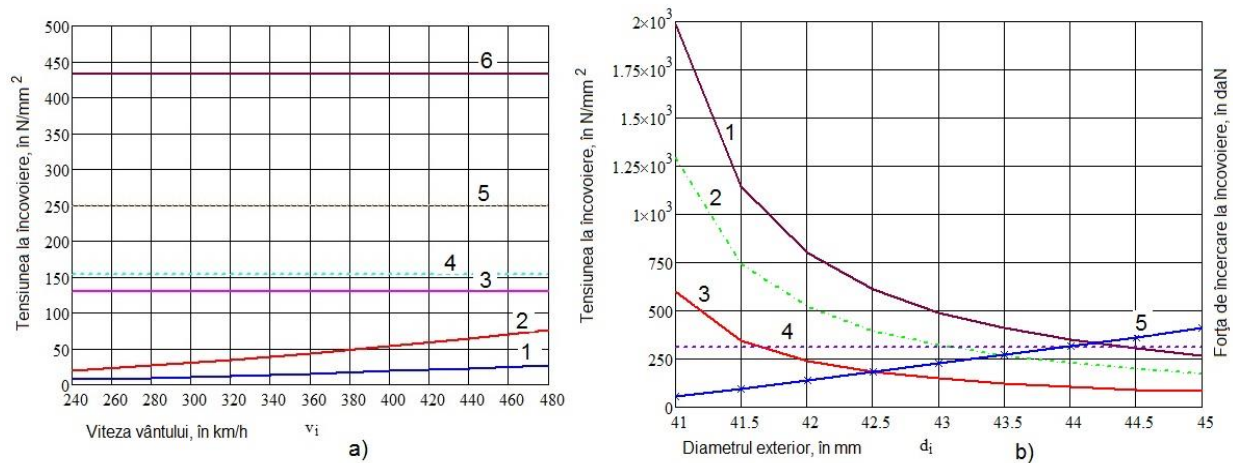


Fig. 3. The variation of the bending tension on the wind speed and exterior diameter of the frangible coupling

In figure 3.b we show the variation of bending tension in the coupling section, according to exterior diameter, curves 1,2 and 3 represent the variation of tension for the maximum, medium and minimum moments.

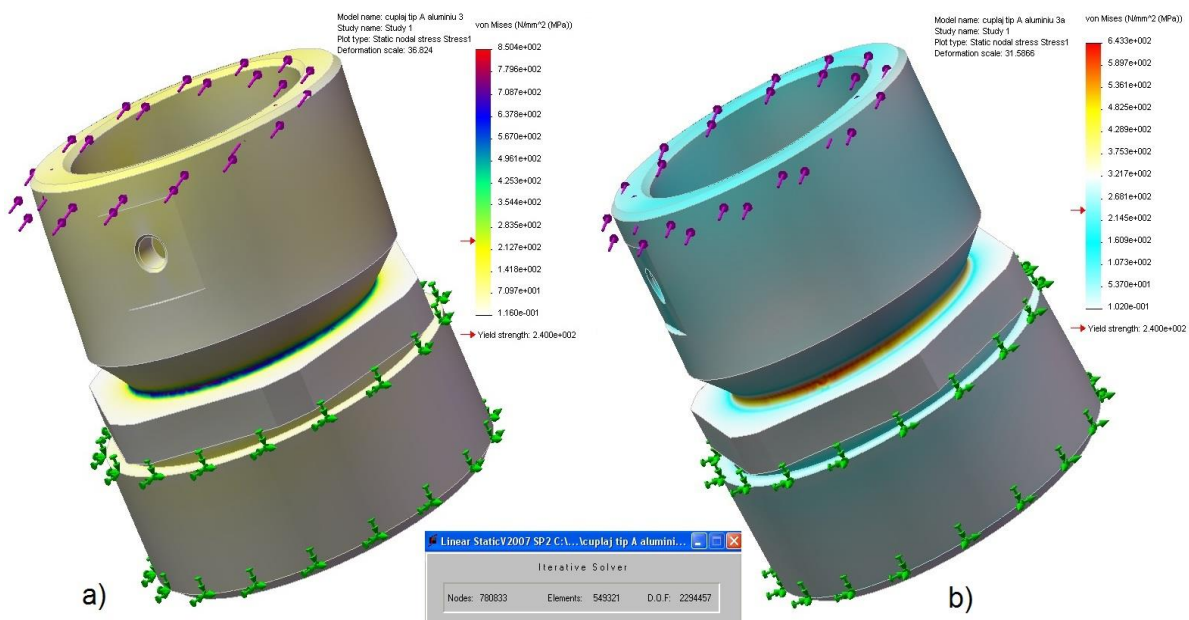


Fig. 4. The variation of the bending tension on the wind speed and the exterior diameter of the section of the frangible coupling

We can see that at a breaking resistance of  $310 \text{ N/square mm}$ , the frangible coupling is made out of aluminium alloy EN WA 6082/SR EN 755-2, curve 4, intersects with the medium tension, curve 2, at an approximate diameter of  $43 \text{ mm}$ . Curve 5 represents the force of pressing for a force arm of  $190 \text{ mm}$ , which, for the  $43 \text{ mm}$  diameter, results in a breaking force of  $240 \text{ daN}$ .

A problem which was analyzed in the calculus program is the behavior of the critical section of the frangible coupling at the phenomenon of tiredness. For a number of  $10^6$  cycles of pulsatory solicitation of the breaking section of the coupling, given by a wind speed of  $240 \text{ km/h}$  and a joining radius in the zone of the breaking of the coupling of  $1 \text{ mm}$ , we obtained a safety coefficient of  $0.876$ , and for a radius of  $0,5 \text{ mm}$ , a safety coefficient of  $0,561$ .

In order to show the influence of the joining radius from the zone of the breaking of the coupling, we undertook an analysis with a finite element of the frangible coupling at the static solicitation given by the maximum moment, in figure 4.a. for a radius of  $0,5 \text{ mm}$  and in the figure 4.b. for a radius of  $1 \text{ mm}$ . We can see that greater tensions have resulted than in the case of the classic formula, and the rapport between the two maximum tensions is  $1.36$  times smaller than the rapport between the coefficients of tiredness resistance of  $1,56$ .

Next, the M10 screws were checked, group 6.8., for the fixing of the base of the signal light on the foundation, regarding the stretching solicitations, crushing of the fillet, and the result was the smallest coefficient of safety at crushing, of  $2,2$ , for the case in which a single screw is at work. Also, the basis of the signal light's support was checked, which, for a sheet of  $10 \text{ mm}$  and a pap of  $69 \text{ mm}$ , did not verify at maximum solicitation, having a safety coefficient of  $0,73$ , and the increaser of the pap's diameter at  $79 \text{ mm}$  was needed, and the coefficient grew at  $1,33$ .

### 3. Establishing the constructive solution for the frangible support for the panel

In figure 5 we show the general design of the panel, which is made up of: 1 – basis 140x300; frangible coupling G2”; 3 – support foot from aluminium tube  $\phi 60 \times 4$ ; 4 – light panel 900x900x100. Based on this constructive solution, a calculus summary was made using the software MathCAD, which allowed the checking of the tube's bending in the fixing zone in the coupling and of the breaking section of the frangible coupling for wind intensities of between 240 and 480 km/h, for an aluminium tube of  $\Phi 60 \times 4$  mm. Also, the support of the light panel must break at a bending moment between 45 and 55 kJ (kNm), if the height of the panel is higher than 1,2 m.

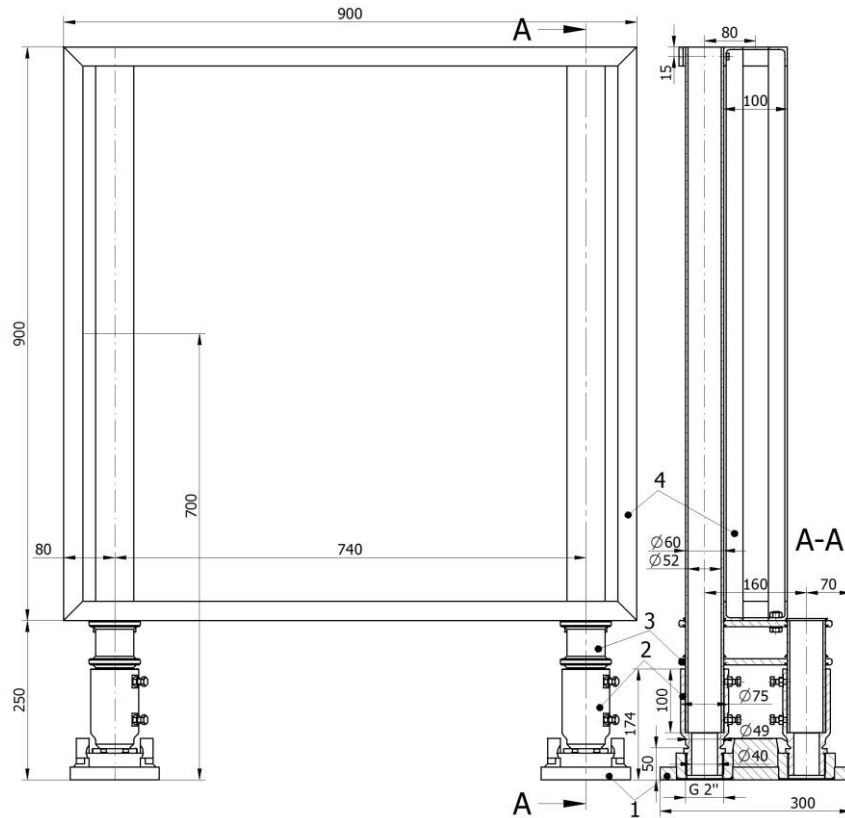


Fig. 5. The constructive solution of the panel's support.

Due to the light panel's dimensions being at the limit, we tried obtaining a support that would resist at the bending moments required by the Manual for designing airfields (ICAO Doc. 9157), Part 6. In order to allow the airship to pass in the case it hit the support structure, the support structure must break, detach or bend to ground level.

With the help of the geometrical characteristics of the critical sections of the support's foot, shown in figure 6, for the zone of the joining of the tube with the frangible coupling (fig.6.a), and for the zone of the breaking of the frangible coupling (fig. 6.b.).

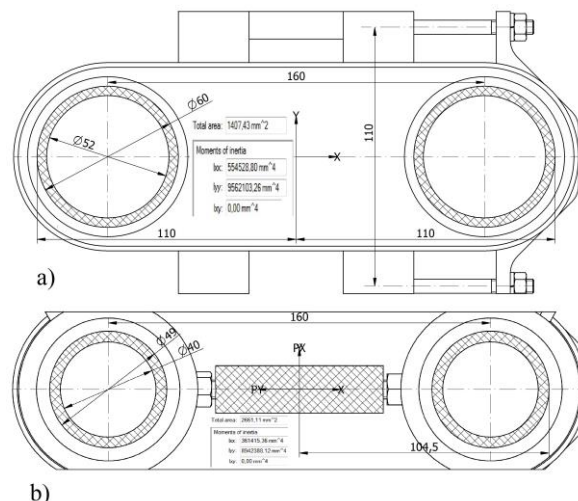


Fig. 6. The geometrical characteristics of the critical sections of the support.



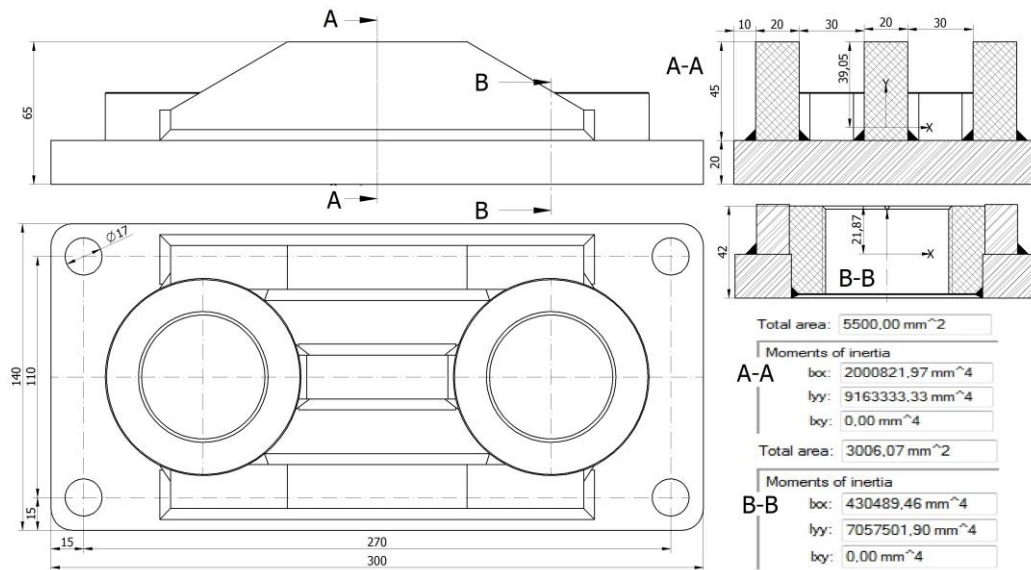


Fig. 7. The constructive form of the foot's basis and the geometrical characteristics of the two critical sections.

For the aluminium alloy EN WA 6082 in N/ square mm, SR EN 755-2, which has a minimum flowing limit of 260 N/square mm and the breaking resistance of 310 N/square mm, the resulting wind safety coefficients for the tube were pf 5,3 and for the moment of maximum breaking of 1,02. These safety coefficients were obtained by rapping to the flowing limit, which excludes the deformation of the tube.

For the zone of the breaking of the support through the frangible coupling, we have obtained wind safety coefficients of 15,8 and at the minimum breaking moment of 1,1 and at the maximum breaking moment of 1,9. These safety coefficients were obtained according to breaking resistance.

An important problem of the support foot of the light panel is the basis, which must resist to the very intense moment of breaking of the support of between 44 and 55 kJ, at half of the foot. In figure 7 we show the constructive solution of the foot's basis, with the geometrical characteristics of the critical sections, for which we obtained safety coefficients of over 1,8.

If the height of the light panel is lower than 1,2 m, we must only check at wind speed, which, through the constructive form of the panel, should not be higher than the bending moment of 240 Nm.

#### 4. Conclusions

With the help of modern designing software, we were able to obtain a quality frangible coupling, which can be added to the portfolio of products of the firm ElectroMax Petroșani (fig. 8).



Fig. 8. Obtain a quality frangible coupling

Due to the construction of the signal light's support, we also modified its construction in comparison with figure 2, and we managed to power it with electrical energy through a cable inserted through the interior of the signal light' support.

In the case of light panels with a height lower than 1,2 m, we can use the support from the signal light, which satisfies the requirement that the device must resist at a bending moment of 204 Nm, but it should break before the bending moment reaches 678 Nm (see figure 1). In this case, we must check at wind speed, which, through the constructive form of the panel, should not be higher than 240 Nm, or, at the limit, the moment of the breaking of the frangible coupling.

For light panels higher than 1,2 m, we can use the constructive solution shown in this paper, with possibilities of improvement, constructively and technologically. Also, we can make a more detailed study of the variation of the distance between the two sustaining branches of the foot and of the support's foot basis.

## **References**

- Buzdugan, Gh., 1979, *Strenght of Materials*, Techincal Publishing House, Bucharest.
- Mănescu, T. Șt. and others, 2005, *Structural analysis using the method of the finite element*, Universitary Horizons Publishing House, Timișoara.
- Muscă, G., 2006, *Assisted designing using Solid Edge*, Junimea Publishing House, Iași.
- \*\*\*, RACR –AD- PETA, *The designing and techincal exploitation of airfields*, second edition/2015.



# The Influence of Humidity on Air Temperature in Underground Mines as a Factor of Air Quality Assessment

Racz Mihaela Dana<sup>a</sup>, Petrilean Dan Codrut<sup>a\*</sup>

<sup>a</sup> University of Petroșani, 20 University street, Petroșani, 332006, Romania

---

## Abstract

Abstract. The relative temperature and humidity of air used in underground works represent its quality factors with predominant influences over the production process and the state of technical comfort. The quantity of condensate of the underground works which is obtained together with the cooling of moist air which goes through them creates major difficulties in the production process. The paper, thus, deals with the determination of the variation of temperature decrease on a meter of underground excavation depending on the inlet temperature and the quantity of condensate formed in underground works which exceed a depth of 200 m. it is useful to know the value for the decrease of the temperature for a meter of underground excavation while carrying out the works for opening a mine and for the preparation of wet galleries in order to dimension the drying installations and / or the pumps used to evacuate the condensate.

*Keywords:* moist air, temperature drop, humidity content, air quality.

---

## 1. Introduction

Due to a series of specific processes which occur on the wet land surfaces (rivers and seas waters, in certain industrial processes, etc.) the surrounding air contains a certain amount of water vapours. The existence of water vapour in the air makes it possible for the transformations of moist air to lead to the production of weather phenomena (rain, snow, glaze ice, white frost, fog, etc.). It is common knowledge that water vapours constitute the most important component of air. There is a constant process in nature of precipitations, water evaporation and transport with the help of the wind. In normal weather conditions the air is able to absorb to saturation either a small or a large quantity of water vapours. The percentage of vapours in air depends on the place and the season. Therefore, the air which enters the underground work is always moist.

The air humidity influences the heat exchange between the human body and the environment. Moreover, the humidity phase changes which occur inside the mine are accompanied by energy transfers which modify in one way or another the value of air temperature. Oniani and Lanchava, 1986 and Lanchava, 1982 have brought forward enlightening aspects concerning the influence the humidity of air has over the underground work, respectively the heat exchange and their weight.

In summer months the air temperature is higher than that on the walls therefore it cools down to the temperature of dew formation at the point when the process of excessive humidity condensation begins. As condensation occurs air heating, its temperature increases slightly and therefore the temperature drop underground in the vicinity of the ventilation shaft shall not be felt. The percentage of vapour content in the air increases in underground works and that is why the paper shall bring forward the cooling action they have on the air. Considering that the change in the humidity content as a function of ventilation way cannot be shown, the following hypotheses are still approved and brought forward by the speciality literature:

1. All the heat from the massif and other heat sources is used to change air temperature and humidity;
2. The relative humidity of the air passing through the mine changes linearly: while it enters the work, the value of the relative humidity of air is  $\varphi_1$ , while in any point which is found at a distance  $l$  (m) from the entrance point it shall be:

---

\* Corresponding author. Tel.: +4 0721373261  
E-mail address: dcpetrilean@yahoo.com.

$$\varphi_2 = \varphi_1 + \frac{\varphi_2 - \varphi_1}{y_1} y = \varphi_1 + \xi y \quad (1)$$

where:  $\varphi_2$  is the relative humidity when it exits the mine, in %;

$y_1$  – is the length of the underground work, in m;

$\xi$  - the increase of relative humidity starting at 1 m from the ventilation way, in %/m.

The relative air humidity allows on its movement trajectory from the superior inlet ramp of the shaft to the longwall modify in the relative restricted limits (in average  $\approx 10\%$ ) (Dosa, 2006).

The change of the underground air humidity is due to the evaporation of water from the open surfaces.

The Mollier diagram is quite useful for the determination of the characteristic parameters of moist air. As this diagram has been established for a 760 mmHg pressure it becomes redundant when it comes to study the changes of the air from underground works where barometric pressure varies with a significant value, rising with roughly 10 mmHg for every 100 m of depth. As the depth of the underground work considered for the study is not that high (approximately 100m) the Mollier diagram was used with oblique coordinates with a pressure of 760 mmHg, the error being therefore accepted.

Underground mines deal with the condensate issue which drips down on the walls of the underground work especially in summer months, the issue therefore substantially changing the comfort of the working conditions. There are, undoubtedly, other downsides which might appear make reference to the state of degradation of the walls of underground works, technical problems and respectively increased costs to remedy them. The usefulness of the study may be found in the documentation prepared for the opening and preparation works of moist galleries where the evaporation of water induces an important cooling of the walls, the dimensioning of the drying installations / the discharge pumps for the water resulted through condensation being of utmost importance.

## 2. Mathematical model

The upper layer of the water in open channels comes into direct contact with the air where a thin layer of air may be separated with the characteristic of having a temperature equal to the temperature of the surface of the water, while its relative humidity is  $\varphi = 1$ . Water evaporates if the molecular pressure of water vapours from the bordering layer exceeds the molecular pressure of water vapours from the air. The diffusion of water vapour from the bordering layer in the direction of a lower pressure is carried out through diffusion or due to convection phenomena. The faster the water vapours drip from the bordering layer the faster and more intense water vapours are formed in order to keep the bordering layer in a state of saturation.

This process enables a two type heat exchange between the water and the air it comes into contact: wither through convection or parallel to the change of weight, i.e. parallel o water evaporation or the condensation of water vapours in the air, when the air loses evaporation heat or receives the heat of the condensation of water vapours. The dimension of the heat exchange is so insignificant that it may be neglected (Lanchava, 1985).

In a horizontal gallery or in a gallery with a slight incline, the increase of the vapour content in the air is almost regular while the cooling of air per meter of gallery may be determined using the following elementary relation:

$$\frac{r}{c_p} \frac{dx}{dy}, \frac{K}{m} \quad (2)$$

where  $r$  is the latent evaporation heat and  $dx/dy$  is the balance of air humidity in relation to the length unit.

The change of the humidity content of the air in the mine occurs after the evaporation of the underground waters on one hand and through the influx of humidity in a gas state from the massif on the other hand (Cioca and Moraru, 2012).

Therefore, the balance of the humidity of air in the mine per meter may be expressed as follows:

$$\frac{dx}{dy} = \frac{W}{\dot{V} \cdot \rho} + \frac{S\sigma}{\dot{V} \cdot \rho} (x_s - x) \quad (3)$$

where:  $W$  is the humidity which exits the massif as gas through the walls of the mine work per length unit expressed in, kg/m s;

$S$  – is the open water surface in the mine work for the entire length, in  $m^2/m$ ;

$x_s$  – the humidity content in a saturation state kg/kg;

$\sigma$  - the substance exchange coefficient in  $kg/m^2 s$ .

The saturated humidity content  $x$  in relation (3) may be determined using the following relation:

$$x_s = \frac{1}{\frac{\varphi}{x} + \frac{\varphi}{0,622} - 1,608}$$

which replaced in (1) results in:

$$\frac{dx}{dy} = \frac{W}{\dot{V} \cdot \rho} + \frac{S\sigma}{\dot{V} \cdot \rho} = \left( \frac{1}{\frac{\varphi}{x} + \frac{\varphi}{0,622} - 1,608} - x \right)$$

or

$$\frac{dx}{dy} = \frac{W}{\dot{V} \cdot \rho} + \frac{2\pi R_0 \sigma}{\dot{V} \cdot \rho} = \left( \frac{1}{\frac{\varphi}{x} + \frac{\varphi}{0,622} - 1,608} - x \right) \quad (4)$$

where  $R_0$  represents the hydraulic radius of the mine work.

Starting from the definition of the degree of saturation:

$$\psi = \frac{x}{x_s} = \varphi \frac{B - p_s}{B - p_v} \cong \varphi \quad (5)$$

The following may be written  $x = x_s \cdot \varphi$  as considering the conditions in the mine the relative humidity has increased values  $0.8 \leq \varphi \leq 1$ .

But, based on additional conditions, i.e. when the barometric pressure remains constant, (for horizontal or slightly inclined mine works) and the partial pressure of the water vapours during saturation is decreased compared to the barometric pressure, namely  $p_s \ll B$ , then  $x_s = f(p_s)$  and therefore for a small range of temperatures the following relations may be used:

$$x_s = \bar{A} + \bar{B} t_a \quad (6)$$

$$x_s = 10^{-3} \left( m + n \cdot t_a + l t_a^2 \right) \quad (7)$$

where:  $\bar{A}$  and  $\bar{B}$  respectively  $m$ , and  $n$  and  $l$  are coefficients the value of which depend on the temperature range chosen.

The  $m$ ,  $n$  and  $l$  coefficients are determined using the equations:

$$4,419 = m + 2n + 2^2 l$$

$$9,450 = m + 13n + 13^2 l \quad (8)$$

$$20,34 = m + 25n + 25^2 l$$

where the values 4.419; 9.450; 20.34 – are the quantities of the water vapours expressed in grams within a kg of air with 100% relative humidity and the temperatures of 2, 13 and respectively 25<sup>0</sup> C for a barometric pressure  $B = 1$  bar.

It results therefore from equations (8) that  $m = 4.013$ ;  $n = 0.164$ ;  $l = 0.01956$  for the temperature range 2-30<sup>0</sup> C. The specific mass heat for a constant pressure is determined using the relation  $c_p = (1-x)1.006 + 1.863x$ .

Nevertheless, the barometric pressure given the conditions of the mine work increases in direct relation to the depth, therefore the quantity of water vapours in the air at a certain temperature in a mine shall be smaller than that corresponding to the same temperature at the surface. It is obvious that at greater mining depths ( $H > 500$  m), when an exact determination is followed, the influence of the barometric pressure over the moisture content of the air is taken into consideration.

Taking into consideration relations (5), (7), (8) the before presented equation (3) becomes:

$$\frac{dx}{dy} = \frac{W}{\dot{V} \cdot \rho} + \frac{2\pi R_0 \sigma (1-\varphi) 10^{-3}}{\dot{V} \cdot \rho} \left( 4,013 + 0,164 t_a + 0,01956 t_a^2 \right) \quad (9)$$

The final form of the equation being:

$$\frac{r}{c_p} \frac{dx}{dy} = \frac{rW}{\dot{m}c_p} + \frac{2\pi R_0 \sigma (1-\varphi) 10^{-3}}{\dot{m} \cdot c_p} (4,013 + 0,164 t_a + 0,01956 t_a^2) \quad (10)$$

In some vertical underground mines there are similar cases to those found in cooling towers where the contact between the ascending air and water is made in two ways:

- when water touches the air through dripping, i.e. when water droplets fall under their own weight in a natural ascending air flow or when it is sucked or discharged by a ventilator. Thus, for a certain flow of water, a contact between water and air is obtained which increases as the droplets become finer, therefore numerous;
- when water trickles along a vertical or an inclined surface through a membrane more or less thin and which may be carried out with or without water losses. Therefore, the resistance when air passes through is smaller than during air-water contact through dripping. The contact surface air-water may thus be determined easier than during the dripping contact.

The determination of the substance transfer coefficient  $\sigma$  is highly dependent on the precision of knowing the contact surface water-air and the characteristics of air for the anarchic variations of the weather conditions. Nevertheless, in isolation, there are mines where the affluence of humidity in a gaseous state from the massif is stopped by the support of the mine while the surface is being moistened through a membrane partially or fully, case where it may be approximated (Pasculescu et al., 2012). Therefore, the precise assessment of the influence of humidity on the temperature of air is carried out using relation (10) measuring the distance between two states, i.e. 1 and 2, and carrying out the balance of the humidity content between the considered states. In the saline the yearly temperature is constant, having a value of 16°C.

### 3. Results

The study has taken into account an underground gallery which has the hydraulic radius  $R = 3\text{m}$ , for which the parameters of moist air known in their initial inlet state and the final gallery state, i.e. the air density ( $1.2 \text{ kg/m}^3$ ); the specific mass heat for its constant pressure ( $1012 \text{ J/(kg}\cdot\text{K)}$ ) and the latent water vaporising heat in  $\text{J/K}$  ( $r = 2500 \text{ J/kg}$ ). Making use of relation (10) a numerical programme was developed for the determination of the variation of temperature drop per meter of underground gallery. Therefore, the coefficient for the exchange of substance was approximated  $\sigma = 0.0142 \text{ kg/m}^2\cdot\text{s}$ . The calculation was carried out for a  $70 \text{ kg/s}$  air mass flow and a 85% respectively 90% relative air humidity at the inlet, values which were determined through precise measurements. The obtained results as well as the temperature drop (dgr) are presented synthetically in tables 1 and 2.

Table 1. The temperature drop for a  $70 \text{ kg/s}$  air mass flow and 90% relative inlet humidity

	Inlet Temp. (°C)	Relative inlet humidity $\varphi(\%)$	Humidity content at the inlet ( $\text{kg}_{\text{water}}/\text{kg}_{\text{dry air}}$ )	Saline Temp. (°C)	Humidity content inside the saline ( $\text{kg}_{\text{water}}/\text{kg}_{\text{dry air}}$ )	$x_1 - x_2$ ( $\text{kg}_{\text{water}}/\text{kg}_{\text{dry air}}$ )	$W_{\text{water}}$ ( $\text{kg}_{\text{water}}/\text{s}$ )	Temperature drop per meter (dgr/m)
1	30	90	$25.2 \cdot 10^{-3}$	16	$11.7 \cdot 10^{-3}$	0.0135	0.945	0.03337
2	28	90	$22 \cdot 10^{-3}$	16	$11.7 \cdot 10^{-3}$	0.0103	0.721	0.0255
3	26	90	$19 \cdot 10^{-3}$	16	$11.7 \cdot 10^{-3}$	$7.3 \cdot 10^{-3}$	0.511	0.018
4	24	90	$17.3 \cdot 10^{-3}$	16	$11.7 \cdot 10^{-3}$	$5.6 \cdot 10^{-3}$	0.392	0.0138
5	22	90	$15.3 \cdot 10^{-3}$	16	$11.7 \cdot 10^{-3}$	$3.6 \cdot 10^{-3}$	0.252	$8.9029 \cdot 10^{-3}$
6	20	90	$13.6 \cdot 10^{-3}$	16	$11.7 \cdot 10^{-3}$	$1.6 \cdot 10^{-3}$	0.112	$3.9622 \cdot 10^{-3}$
7	18	90	$12 \cdot 10^{-3}$	16	$11.7 \cdot 10^{-3}$	$3 \cdot 10^{-4}$	0.021	$7.5073 \cdot 10^{-4}$

Table 2. Temperature drop for a 70 kg/s air mass flow and a 85% relative inlet humidity

	Inlet Temp. (°C)	Relative inlet humidity $\phi(\%)$	Humidity content at the inlet (kg <sub>water</sub> /kg <sub>dry air</sub> )	Saline Temp. (°C)	Humidity content inside the saline (kg <sub>water</sub> /kg <sub>dry air</sub> )	$x_1-x_2$ (kg <sub>water</sub> /kg <sub>dry air</sub> )	$W_{\text{water}}$ (kg <sub>water</sub> /s)	Temperature drop per meter (dgr/m)
1	30	85	$23.4 \cdot 10^{-3}$	16	$11.7 \cdot 10^{-3}$	$0.0117$	0.819	0.02892
2	28	85	$21 \cdot 10^{-3}$	16	$11.7 \cdot 10^{-3}$	$9.3 \cdot 10^{-3}$	0.651	0.023
3	26	85	$18.6 \cdot 10^{-3}$	16	$11.7 \cdot 10^{-3}$	$6.9 \cdot 10^{-3}$	0.483	0.0171
4	24	85	$16.5 \cdot 10^{-3}$	16	$11.7 \cdot 10^{-3}$	$4.8 \cdot 10^{-3}$	0.336	0.0119
5	22	85	$14.5 \cdot 10^{-3}$	16	$11.7 \cdot 10^{-3}$	$2.8 \cdot 10^{-3}$	0.196	$6.9314 \cdot 10^{-3}$
6	20	85	$12.9 \cdot 10^{-3}$	16	$11.7 \cdot 10^{-3}$	$9 \cdot 10^{-3}$	0.063	$2.2378 \cdot 10^{-3}$
7	18	85	$11.9 \cdot 10^{-3}$	16	$11.7 \cdot 10^{-3}$	$2 \cdot 10^{-4}$	0.014	$5.0851 \cdot 10^{-4}$

The dependencies of the temperature drop per meter of underground work were drawn in figure 1 considering the inlet temperature and the condensed water for a 90% and 85% relative humidity, knowing the values for the inlet moist air and the radius of the underground work, based on the values obtained in tables 1 and 2.

Analysing the data in figure 1 the following conclusion may be drawn: the temperature drop depending on the inlet temperature of air and the flow of water which is condensed bring forward a variation following an exponential curve presenting a slope as close to the vertical position as the relative humidity of air increases.

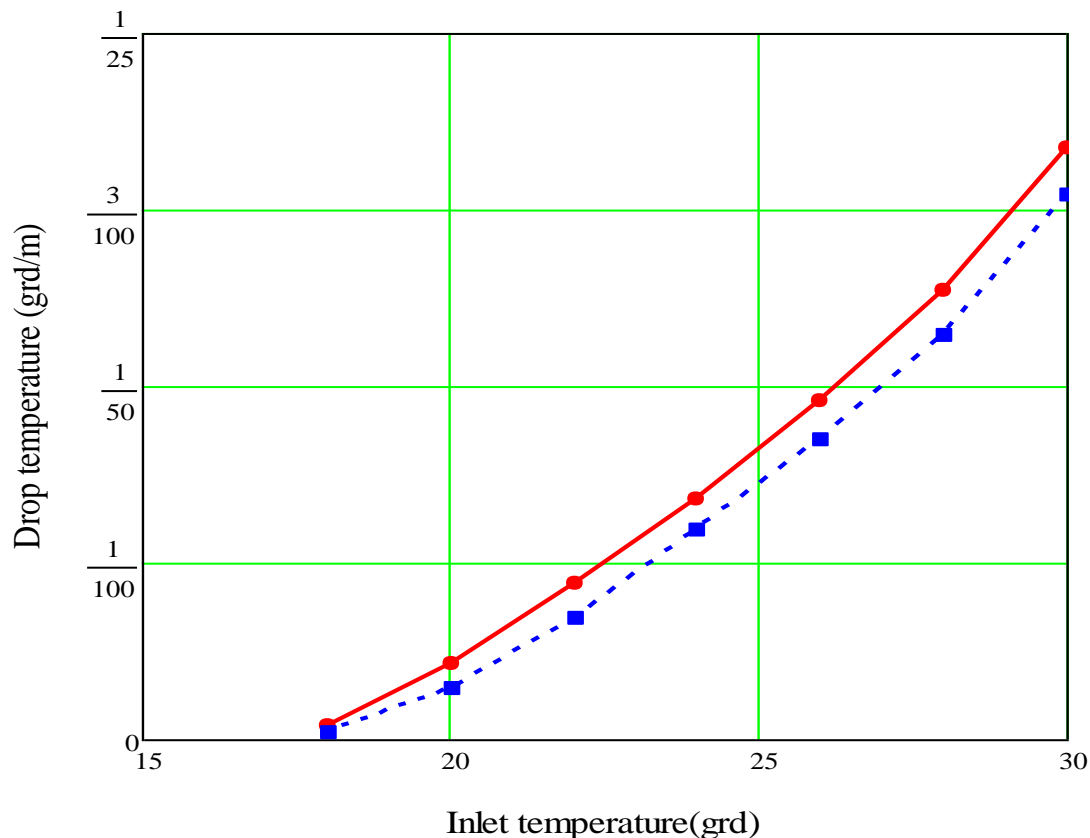


Fig. 1. The variation of temperature drop depending the inlet moist air and the condensed water flow for a 90% relative humidity (continuous line) respectively 85% (dotted line) and 70 kg/s moist air flow

#### 4. Conclusions

Estimating the temperature drop per meter of underground work represents a very useful information when dealing with the technical documentation necessary for the works carried out to open the wet galleries in order to dimension the drying installations and / or the pumps used to remove the condensed water. Knowing the parameters of air at the gallery inlet (the temperature on the abscissa) and the mass flow of moist air on the vertical and intersecting the drawn curves the value of the temperature drop is obtained on the ordinate with a satisfying precision. (Figure 1).

#### References

- Oniani, S.I., Lanchava, O.A., *Concerning the thermo-moisture transfer in a massif*, Bulletin of the Academy of Sciences of the Georgian SSR. Vol. 123, Issue 1, pp. 122-124, (1986).
- Lanchava, O.A. *Heat and mass exchange in permanent mine workings*, Soviet Mining Science, 18(6), pp. 529-532, (1982).
- Doşa, I., *Modelling complex compressed air networks in order to improve the speed of calculus*, Annual of the University of Mining and Geology "St. Ivan Rilski", vol. 49, part III, pp. 15-20, 2006
- Lanchava, O.A., *Heat and mass exchange in newly driven mine workings*, Soviet Mining Science, 21(5), pp. 460-464, (1985).
- Cioca, I.L., Moraru, I.R., *Explosion and/or fire risk assessment methodology: a common approach, structured for underground coalmine environments*, Journal Archives of Mining Sciences, Vol. 57, Issue 1, pp. 53-60, (2012).
- Păsculescu, D., Leonard Lupu, L., Păsculescu, V., Inişconi, I., Şuvar, M., *Study of electrocution hazards in three-phase electrical networks with ground-isolated neutral point*, Environmental Engineering and Management Journal, Vol. 11, No. 7, (2012).

## The Assessment of Factors Which Influence the Energetic Efficiency of Helical Screw Compressors Found in Coal Mines

Adriana Zamora<sup>a\*</sup>, Sorina Stănilă,<sup>a</sup>

<sup>a</sup>University of Petrosani, 20 University Street, 332006, Petroșani, Hunedoara County, Romania

---

### Abstract

The use of pneumatic energy in industry and in the tertiary sector is quite frequent, the production and consumption of compressed air being carried out without any serious technical difficulties or hazards. The energetic balance of the European Union comprises the energetic consumption for the production of compressed air which is  $80 \div 100$  TWh, the pneumatic energy representing  $10 \div 12$  % of the industrial electricity consumption.

It must be therefore shown that there is a reduced energetic efficiency of pneumatic systems, the case studies highlighting the possibility to increase it as long as a series of technical solutions are implemented allowing thus energetic economies of  $5 \div 50$  %. Unfortunately, the actual community market conditions and the decision mechanisms do not allow the practical application of such an important energy saving potential.

The lifespan of compressors is relatively long, i.e. an average of 14 years for those with the power comprised between 10 and 90 kW and respectively 16 years for the compressors with the power comprised between 90 and 300 kW. The average yearly operation period of the compressors is 3500 hours/year.

The present paper highlights that the technical measures destined to increase the energetic efficiency are feasible and profitable, the first steps consisting in the implementation of a series of measures to organise and meter the consumption and to assess the cost of compressed air followed by the development of the consumption management structures and investments.

*Keywords:* compressed air; helical screw compressor; energetic balance.

---

### Introduction

#### 1. General considerations regarding the constructive characteristics of helical screw compressors

Helical screw compressors belong to the rotary screw compressors category. Eliminating the crank mechanism of the reciprocating compressor this type of machines brings forward a balanced operation having superior isothermal efficiencies and flow coefficients compared to other types of compressors. The category of helical screw compressors or expanders is well represented nowadays by a large variety of constructive and operational types leading therefore to an important increase in the number of units in the past years, representing approximately 80% of the number of sold screw compressors, 50% of them being found in operation. They operate with a wide range of liquids which may be gases, dry vapours or multiphase liquids, the change of the phases occurring inside the machine. The helical screw compressor may have a dry operation (without any oil injection), with oil injection or using other injected fluids during gas compression. In order to obtain the maximum value of the efficiency of this type of machine a special design and operation is imposed. It is therefore impossible to produce effective machineries by specifying a universal configuration of the rotor or by imposing a series of operational parameters even for a reduced class of machines.

The helical screw compressor is composed of two rotors, one being the male rotor and the other the female rotor. The rotors of the screw compressor contain a number of lobes each pair of lobes forming a helical thread. The number of lobes depends on the necessary sliding surface, being common knowledge that a lower number of lobes allow a larger sliding surface generating a pressure increase between the lobes.

The suction and discharge openings are placed in the frontal lids of the cylinder. The gas enters the helical threads which communicate in a certain succession with the suction opening. When the threads are disconnected from the

---

\* Corresponding author: Adriana ZAMORA - Tel.: +40 724 361 686.  
E-mail address: adrianazamora2001@yahoo.com



opening, gas is isolated in a chamber created by the helical threads of the rotors and the casing of the compressor. Then, within the threads of the driven rotor, the lobes of the driving rotor are inserted and thus the volume of the gas chamber decreases the gas being driven onto an axial direction and compressed in the same time until the helical threads are connected to the discharge opening found in the opposite lid of the cylinder. Rotors therefore, once they move the gas from the aspiration opening to the discharge one, they also carry out a compression of the gas depending on the variation of the volumes of the spaces inside the threads.

The suction, compression and discharge of the gas are carried out successively in each thread, formed by a pair of conjugated lobes. Therefore, the final pressure of the thread when this is connected to the discharge valve does not depend on the network counter pressure but on the geometry of the rotors and the position of the discharge opening. The helical screw compressor should be used when there is a constant pressure in the discharge pipe to the network.

## 2. The exergetic balance of the INGERSOLL RAND compressor unit

### Average values of the experimentally determined thermal-fluidic parameters INGERSOLL RAND SSR M-250 type compressor

$$\begin{aligned}
 \psi_a &:= 0.24 & \psi_r &:= 0.12 & \eta_m &:= 0.8 & \phi_a &:= 1.05 & \phi_r &:= 1.03 & k &:= 1.4 \\
 R_g &:= 0.287 \text{ kJ/kg}\cdot\text{K} \\
 T_a &:= 282 & \text{temperature during suction} \\
 T_0 &:= 287.3 & \text{environmental temperature} \\
 T_c &:= 416 & \text{temperature at the end of compression} \\
 T_r &:= 376 & \text{temperature during discharge} \\
 p_a &:= 0.954 & \text{suction pressure, bar} \\
 p_c &:= 6.3 & \text{compression pressure, bar} \\
 Q &:= 2280.5 & m^3_N/h \\
 Q &:= 2280.5 & m^3_N/h \\
 nc &:= \frac{1}{1 - \frac{\ln(T_a/T_c)}{\ln(p_a/p_c)}} & nc &= 1.259 \\
 \Psi &:= (1 - \psi_a)(1 - \psi_r) & \Psi &= 0.669 \\
 H_m &:= \frac{p_c}{p_a} & H_m &= 6.604 \\
 \beta &:= \frac{H_m}{\Psi} & \beta &= 9.874 \\
 T_a &= \phi_a \cdot T_0 & T_a &= 301.665 \\
 T_c &:= T_a \cdot \beta^{\frac{(nc-1)}{nc}} & T_c &= 483.449 \\
 T_r &:= \frac{T_c}{\phi_r} & T_r &:= 449.368 \\
 1T_0 &:= R_g \cdot T_0 \cdot \ln(H_m) \\
 1T_0 &= 155.6456 & \text{kJ/kg}
 \end{aligned}$$

The revision tables for the components of the compressor unit are thus brought forward.

Table 1. Revision table for the real hourly exergetic balance for the INGERSOLL RAND SSR-250 MV type compressor

EXERGY ENTERED INTO THE OUTLINE			OUTLINE OUTPUT EXERGY		
Name	kWh	%	Name	kWh	%
<b>USEFUL EXERGY</b>					
Exergy at the shaft of the compressor	259.36	100	Compression process exergy	127.49	49.15
			Losses through lamination during suction	18.54	7.15
			Losses through lamination during discharge	8.64	3.33
			Losses with the heat given off during compression	14.75	5.68
			Losses with the heat given off during discharge	4.61	1.77
			Losses with the heat given off during isobaric cooling	33.46	12.93
			Mechanical losses	30.06	11.59
			Losses due to air humidity	21.81	8.4
			Total losses	131.87	50.85
<b>Total</b>	<b>259.36</b>	<b>100</b>	<b>Total</b>	<b>259.36</b>	<b>100</b>

Table 2. Tabel recapitulativ pentru bilanțul exergetic real orar motor acționare INGERSOLL

EXERGY ENTERED INTO THE OUTLINE			OUTLINE OUTPUT EXERGY		
Name	kWh	%	Name	kWh	%
Exergy supplied from the network	283.46	100	<b>USEFUL EXERGY</b>		
			Exergy at the shaft of the motor	259.36	91.50
			<b>LOST EXERGY</b>		
			Losses in copper at the coil	3.76	1.33
			Losses in copper at the rotor	3.6	1.27
			Losses in iron	9.5	3.35
			Mechanical losses	7.24	2.55
			Total losses	24.1	8.5
<b>Total</b>	<b>283.46</b>	<b>100</b>	<b>Total</b>	<b>283.46</b>	<b>100</b>

Table 3. Revision table for the real hourly exergetic balance of the INGERSOLL-RAND type ventilator

EXERGY ENTERED INTO THE OUTLINE			OUTLINE OUTPUT EXERGY		
Name	kWh	%	Name	kWh	%
Exergy at the shaft of the ventilator	11.95	100	<b>USEFUL EXERGY</b>		
			Air flow exergy	8.622	72.15
			<b>LOST EXERGY</b>		
			Mechanical losses	0.906	7.58
			Fluid losses	1.696	14.19
			Volume losses	0.726	6.08
			Total losses	3.328	27.85
<b>Total</b>	<b>11.95</b>	<b>100</b>	<b>Total</b>	<b>11.95</b>	<b>100</b>

$$Q = 8,78 \text{ m}^3/\text{s};$$

$$\Delta p = 100 \text{ mm H}_2\text{O};$$

$$\eta = 72.15\%$$

$$P_{\text{useful}} = 8.622 \text{ kW};$$

$$P_{\text{motor shaft}} = 11.95 \text{ kW};$$

$$\text{Ventilator losses} = 3.328 \text{ kW}$$

Table 4. Revision table for the real hourly exergetic balance of the INGERSOLL ventilator driving motor

EXERGY ENTERED INTO THE OUTLINE			OUTLINE OUTPUT EXERGY		
Name	kWh	%	Name	kWh	%
Exergy supplied from the network	14.475	100	<b>USEFUL EXERGY</b>		
			Exergy at the shaft of the motor	11.95	82.55
			<b>LOST EXERGY</b>		
			Losses in copper at the coil	0.77	5.33
			Losses in copper at the rotor	0.635	4.38
			Losses in iron	0.82	5.67
			Mechanical losses	0.30	2.07
			Total losses	2.525	17.45
<b>Total</b>	<b>14.475</b>	<b>100</b>	<b>Total</b>	<b>14.475</b>	<b>100</b>

Table 5. Revision table for the real hourly exergetic balance of the **INGERSOLL RAND SSR-250 MV** screw compressor unit

EXERGY ENTERED INTO THE OUTLINE			OUTLINE OUTPUT EXERGY		
Name	kWh	%	Name	kWh	%
Exergy supplied from the network to the motor of the compressor	283.46	94.63	<b>USEFUL EXERGY</b>		
			Useful exergy of compressed air	127.49	42.80
			Useful exergy of cooling air	8.622	2.89
			Total useful exergy	136.112	45.69
			<b>LOST EXERGY</b>		
			Losses through lamination during suction $\pi_{la}$	18.54	6.22
			Losses through lamination during discharge $\pi_{lr}$	8.64	2.90
			Losses with the heat given off during compression $\pi_{qc}$	14.75	4.95
			Losses with the heat given off during discharge $\pi_{qr}$	4.61	1.55
			Losses with the heat given off during isobaric cooling $\pi_{\Delta T}$	33.46	11.23
Exergy supplied from the network to the motors of the ventilators	14.475	5.37	Mechanical losses $\pi_m$	30.06	10.09
			Losses due to air humidity	21.81	7.32
			Ventilator mechanical losses $p_{mv}$	0.906	0.3
			Ventilator fluidic losses $p_{fv}$	1.696	0.57
			Ventilator volume losses $p_{vv}$	0.726	0.25
			Losses in copper at the motor of the ventilator $p_{Cu v}$	1.405	0.47
			Losses in iron at the motor of the ventilator $p_{Fe v}$	0.82	0.27
			Mechanical losses at the motor of the ventilator $p_{mv}$	0.3	0.11
			Losses in copper at the motor of the compressor $p_{Cu c}$	7.36	2.47
			Losses in iron at the motor of the compressor $p_{Fe c}$	9.5	3.18
<b>Total</b>	<b>14.475</b>	<b>100</b>	Mechanical losses $p_{mc}$	7.24	2.43
			Total losses	161.823	54.31
<b>Total</b>	<b>14.475</b>	<b>100</b>	<b>Total</b>	<b>297.935</b>	<b>100</b>

Table 6. Revision table for the optimum hourly exergetic balance of the **INGERSOLL RAND SSR-250 MV** screw compressor unit

EXERGY ENTERED INTO THE OUTLINE			OUTLINE OUTPUT EXERGY		
Name	kWh	%	Name	kWh	%
Exergy supplied from the network to the motor of the compressor	230.329	94.08	<b>USEFUL EXERGY</b>		
			Useful exergy of compressed air	127.49	52.08
			Useful exergy of cooling air	8.622	3.52
			Total useful exergy	136.112	55.6
			<b>LOST EXERGY</b>		
			Losses through lamination during suction $\pi_{la}$	18.54	7.57
			Losses through lamination during discharge $\pi_{lr}$	8.64	3.53
			Losses with the heat given off during compression $\pi_{qc}$	2.95	1.2
			Losses with the heat given off during discharge $\pi_{qr}$	0.93	0.38
			Losses with the heat given off during isobaric cooling $\pi_{\Delta T}$	6.702	2.74
Exergy supplied from the network to the motors of the ventilators	14.475	5.92	Mechanical losses $\pi_m$	30.061	12.29
			Losses due to air humidity	10.912	4.46
			Ventilator mechanical losses $p_{mv}$	0.907	0.38
			Ventilator fluidic losses $p_{fv}$	1.697	0.69
			Ventilator volume losses $p_{vv}$	0.727	0.29
			Losses in copper at the motor of the ventilator $p_{Cu v}$	1.406	0.58
			Losses in iron at the motor of the ventilator $p_{Fe v}$	0.82	0.33
			Mechanical losses at the motor of the ventilator $p_{mv}$	0.3	0.12
			Losses in copper at the motor of the compressor $p_{Cu c}$	7.36	3
			Losses in iron at the motor of the compressor $p_{Fe c}$	9.5	3.88
<b>Total</b>	<b>14.475</b>	<b>100</b>	Mechanical losses $p_{mc}$	7.24	2.96
			Total losses	108.692	44.4
<b>Total</b>	<b>14.475</b>	<b>100</b>	<b>Total</b>	<b>244.804</b>	<b>100</b>

### 3. Technical-managerial measures destined to increase the energetic efficiency of pneumatic generators used in coal mines:

- The recovery of heat exhausted while cooling down the compressed air, its thermal potential being used through an adequate recovery system in order to heat the locker room of the mine workers, to avoid the appearance of ice on the guiderail of the mining installation or to heat the water necessary for the restrooms;
- Actions to eliminate humidity from the discharged compressed air;
- Ensuring a consumption chronogram for the compressed air in order to flatten out the load curve;
- The introduction of electric control panels for the operation of compressors fitted with variable revolution motors (VSD);
- The introduction of a detailed monitoring of the consumption of compressed air.

#### 3.1. Measures to be carried out with small investments

The reduction with 80 % of the heat losses at the compressor unit  
INGERSOLL RAND type compressor

- The reduction of losses with the heat given off during compression with 11.8 kWh;
- The reduction of losses with the heat given off during discharge with 3.68 kWh;
- The reduction of losses with the heat given off during isobaric cooling with 26.76 kWh;
- The total value of the reduction of the losses shall amount to 42.25 kWh.

#### 3.2. Measures to be carried out with large investments

INGERSOLL RAND type compressor

- Economising the energy supplied from the network  $\Delta E = 43 \text{ kWh} = 154.8 \text{ MJ} = 3.7 \cdot 10^{-3} \text{ t.e.p.}$
- The value for the energetic economy  $VE = (3.7 \cdot 10^{-3} \text{ t.e.p./h}) 625\text{€}/\text{tep} = 2.3 \text{ €/h}$
- The value for the investment  $I = 283.46 \text{ kWh} \cdot 300 \text{ €/kWh} = 85,038 \text{ €}$
- The investment recovery period  $IRP = I/VE = 85,038/2.3 = 36,973 \text{ Hours} = 1,540 \text{ Days} = 5.83 \text{ Years}$ .

### Conclusions

The use of pneumatic energy in industry and the tertiary sector is quite frequent, representing therefore 10% of the European industrial electricity consumption, the lifespan of compressors being relatively long, namely an average of 14 to 16 years of operation depending on their installed power.

The energetic efficiency of pneumatic systems is reduced, the studies carried out in this regard highlighting the possibilities to increase it considering the implementation of technical solutions which allow the realisation of energetic economies between 5 ÷ 50%.

Although the demand of compressed air at Lonea Coal Mine is ensured by modern efficient compressors manufactured by famous companies (i.e. ATLAS COPCO, INGERSOLL RAND), there are still countless possibilities to increase their energetic efficiency through:

- The recovery of heat given off through the cooling of compressed air;
- Actions to eliminate the humidity of discharged compressed air;
- Ensuring the creation of a compressed air consumption chronogram in order to flatten the load curve;
- • The introduction of electronic control panels for the operation of compressors fitted with variable revolution motors (VSD);
- The introduction of a detailed monitoring of the consumption of compressed air;
- The parallel operation of low voltage transformers on a load curve based on minimum power losses depending on the variation of the load.

Although all the measures proposed for the improvement of energetic efficiency are feasible and cost effective, the companies are not interested in applying them due to a series of organisational deficiencies such as:

- The lack of metering devices for the consumption and respectively the cost of compressed air;
- The lack of information regarding possible economies;
- The complexity of the structures for the management of energy consumption.

## References

- Doşa, I., *Energetica reţelelor pneumatice*, TehnoArt Publishing Petroşani, Romania, (2003).
- Fotău, I., *Electroenergetica*, Universitas Publishing Petroşani, Romania, (2003).
- Irimie, I.I., *Analiza exergetică a proceselor din reţelele pneumatice miniere*, Conference of energetic, section 14, Bucharest, Romania, (1986).
- Păsculescu, D., Pădure, A., *Instalaţii electrice*, Universitas Publishing, Petroşani, Romania, (2010).
- Petrilean, D.C., Doşa, I., Pădure, A., Pană, L., Popescu, F., Zamora, A. et al., *Elaborare audit energetic pentru un contur definit la E.M.Lonea*, Scientific Research Contract, Romania, (2012).

## Modeling and Simulation of the Sterile Rocks Excavation Process using Bucket Wheel Excavators

Olimpiu Stoicuța<sup>a</sup>, Marin Nan<sup>a</sup>, Danuț Grecea<sup>b\*</sup>, Cătălin Plotogea<sup>a</sup>

<sup>a</sup>University of Petrosani, 20 University street, 332006, Petrosani, Romania

<sup>b</sup>National Institute for Research and Development in Mine Safety and Protection to Explosion-INSEMEX Petrosani

---

### Abstract

This paper presents the modeling and simulation of the sterile rocks excavation process using bucket rotor excavators. The modeling and simulation of the excavation process is carried out in Matlab-Simulink, based on an original mathematical model of the momentary capacity.

*Keywords:* bucket wheel excavator, induction motors; scalar control system.

---

### 1. Introduction

The excavation process of sterile rocks can be done in a cost-effective manner, both technically and energetically, only when the parameters characterizing this process, their interdependence, and the ways to improve the technical-economic indices that define the phenomenon of excavation are known.

Defining the excavation parameters, establishing them, as well as finding the relationships of interdependence, represents an important and not at all negligible problem if it is desired to know the excavation process in its depth.

Knowing these aspects does not solve the problem without performing a technological analysis of the excavation process. For this reason, this paper presents the analysis by modeling and simulation in the Matlab Simulink of the excavation process of the sterile rocks by means of bucket rotor excavators.

The analysis of the technological process of excavation is a research area dealt with over the past decade by several researchers including: Bosnjak (2006), Dandea (2013), Durst (1988), Haliti (2016), Jevtovic (2004), Ladanyi (2006), Nan (2007), Nan (2008), Pajer (1971), Petrovic (2006), Rasper (1975), Sharma (2009), Vetrov (1971).

The most important aspect of the current research, regarding the automatic driving of the bucket rotor excavators is the relatively constant maintenance with minimal variations of the material flow on the conveyor, within a swinging cycle of the excavator. Among the most recent research in this regard, we mention the following: Bosnjak (2015), Che (2014), Dandea (2013).

The main two advantages of constantly maintaining the flow of material on the conveyor belt are: reducing energy consumption and increasing the reliability of the components of the transport technology system. By constantly maintaining the flow of material on the conveyor belt, all machinery that is part of the transport technology flow can be chosen optimally so that they can be used intensively at nominal capacity.

In the simulation of the excavation process in this article, are surprised the dynamic effects introduced by the induction machines and the gearboxes acting on the port-cups wheel and the excavator's top platform. In the simulation of the port - cup wheel drive system, the gear shifter of this system is also considered.

Following the simulations are present and analyzed the variations in time of the flow coal load on the conveyor belt, variations in time of the pivoting speed and of the cutting speed over time for two distinct pivoting cycles. Simulations are customized for the EsRc 1400 rotor excavator. The results obtained from the research conducted in this article allow to highlight the possibilities of improving the cutting-loader system of the bucket rotor.

---

\* Corresponding author. Tel.: +40 0723 809 482; fax: +40 254 546 277  
E-mail address: greceadanut@gmail.com

## 2. The momentary capacity

The most commonly used technology for mechanized extraction of lignite at the surface, is based on the excavation of the working steps above the level of the excavator, and based on the method of excavation with vertical multi-row chips (see Fig. 1).

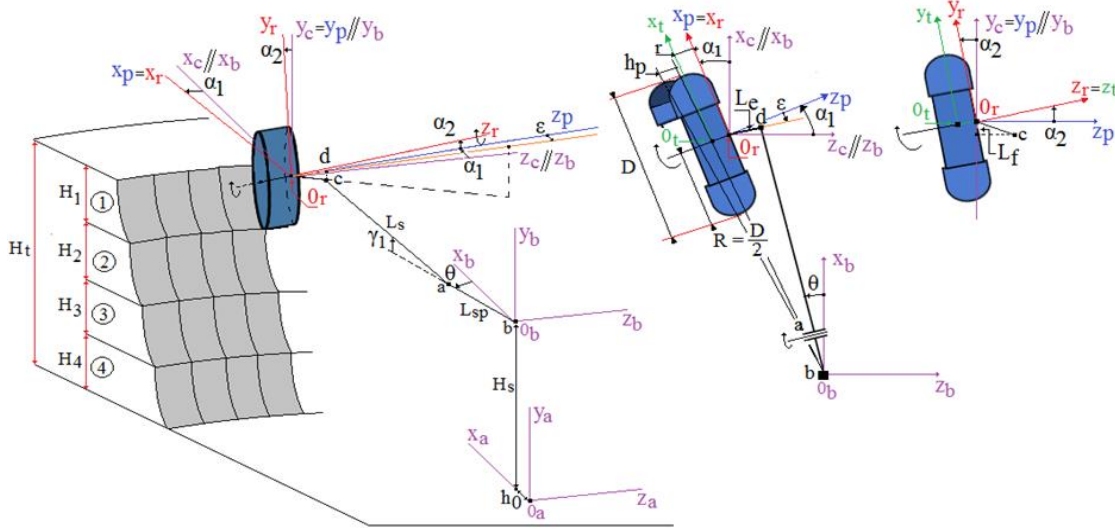


Fig. 1. Excavation with vertical multi-row chips

In Fig. 1, the following notations were used:  $H_t$  is height of the working step;  $H_i$  the height of the slice  $i$ , ( $i=1 \div 4$ );  $D$  represent the rotor cutting diameter;  $a$  the axis of rotation of the bucket wheel arrow;  $b$  the axis of rotation of the upper plat-form;  $L_{sp}$  is distance between the axis of rotation of the bucket wheel arrow and the axis of rotation of the upper platform;  $H_s$  is height of axis of boom rotation to the level of operating the excavator;  $\gamma_i$  ( $i=1 \div 4$ ) represents the apex angle of the bucket wheel boom to plane  $X_b O_b Z_b$ ;  $L_s$  is bucket wheel boom length;  $\theta$  is the bucket wheel boom position angle to axis  $O_b X_b$ ;  $h_0$  is the maximum cutting depth;  $h_p$  is the width of the cut defined by the distance between the moving adjacent scoops and pass through the horizontal plane  $X_b O_b Z_b$ ;  $\alpha_1$  is the angle in horizontal plane between the axis system  $X_c O_r Z_c$  and the axis system  $X_p O_r Z_p$ ;  $\alpha_2$  is the angle in vertical plane between the axis system  $Y_p O_r Z_p$  and the axis system  $Y_r O_r Z_r$ ;  $L_e$  is the distance between  $d$  (resulted after projecting  $c$  onto the horizontal plane  $X_c O_r Z_c$ ) and  $O_r$  in the horizontal plane  $X_c O_r Z_c$ , this distance defines the eccentricity of the bucket wheel in the horizontal plane;  $L_f$  is the distance between  $c$  and  $d$  in the vertical plane  $Y_r O_r Z_r$ , this distance defines the eccentricity of the bucket wheel in the vertical plane;  $\varepsilon$  is the inclination angle in horizontal plane measured between axis  $O_r Z_p$  and the line which passes through  $O_r$  and  $d$ ;  $r$  is the distance between the rotation plane  $O_r X_r Y_r$  and the cutting plane  $O_r X_t Y_t$ .

From the Fig. 1 it is observed that the cutting process is done by combining the rotation of the bucket wheel in the vertical cutting plane and the slewing of the upper platform of the excavator in the horizontal plane  $X_b O_b Z_b$ .

The main parameters of the cutting process described in Fig. 1, for  $\alpha_1 = \alpha_2 = \varepsilon = 0^\circ$  and  $L_e = L_f = r = 0$ , are represented in Fig. 2.

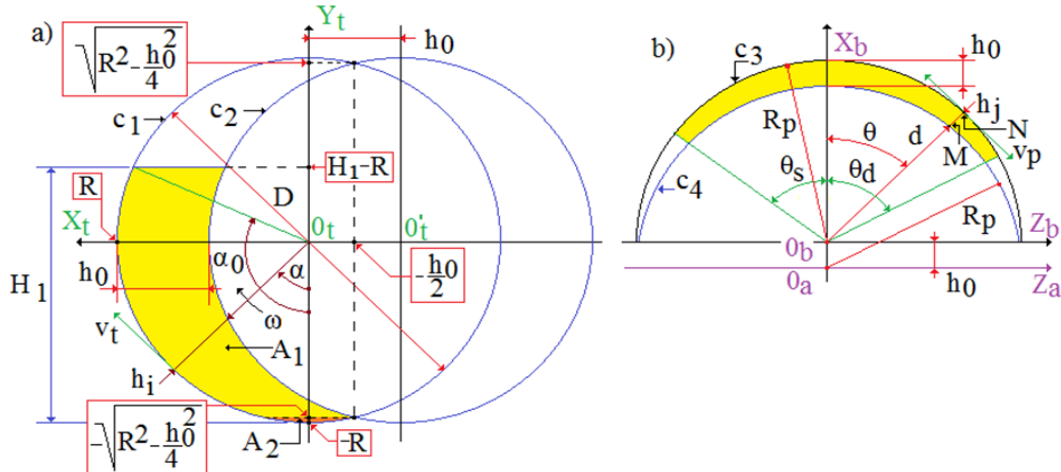


Fig. 2. The parameters of the cutting process. a) in the main vertical plane; b) in the main horizontal plane.



The momentary capacity of excavating of the bucket wheel excavators can be obtained with the following expression

$$Q_m(\theta) = \frac{n_c \cdot n_t}{60} \cdot \int_{\theta}^{\theta + \frac{2 \cdot \pi \cdot n_p}{n_c \cdot n_t}} A_j(\theta_m) \cdot [R_p - R + x_c^j(\theta_m)] d\theta_m \quad (1)$$

where:

- $A_j$  is the surface of the cut in a cutting plane situated at an angle  $\theta$  in relation to the main plane

$$A_j = h_j \cdot (H_1 - R) + \frac{\pi \cdot R^2}{2} - R^2 \cdot \text{asin} \left( \sqrt{1 - \frac{h_j^2}{4 \cdot R^2}} \right) + \frac{h_j}{2} \cdot R \cdot \sqrt{1 - \frac{h_j^2}{4 \cdot R^2}} \quad (2)$$

- $x_c^j$  is the abscissa of the centroid chip in the main vertical plane

$$x_c^j = \frac{1}{A_j} \cdot \left[ \frac{h_j \cdot (R - H_1) \cdot (h_j - M_a)}{2} + \frac{2 \cdot R^3}{3} - \frac{(2 \cdot R^2 + h_j^2) \cdot \sqrt{4 \cdot R^2 - h_j^2}}{6} + \frac{R^2 \cdot h_j \cdot \delta_j}{2} \right] \quad (3)$$

$$\delta_j = \text{asin} \left( \sqrt{1 - \frac{h_j^2}{4 \cdot R^2}} \right) + \text{asin} \left( \frac{H_1}{R} - 1 \right); M_a = \sqrt{2 \cdot H_1 \cdot R - H_1^2} \quad (4)$$

- $h_j$  is the distance between  $M$  and  $N$  points

$$h_j = \left| R_p + h_0 \cdot \cos(\theta) - \sqrt{R_p^2 - h_0^2 \cdot \sin^2(\theta)} \right| \quad (5)$$

In the above relationships, or use the following notations:  $n_c$  is number of spoons,  $n_t$  is speed of the wheel with spoons,  $R_p$  represents the slewing radius,  $|\cdot|$  is absolute value and  $n_p$  is slewing speed.

Under these conditions, it was kept in mind that the time of the cycle for discharging a spoon,  $\Delta T$  is equal to the running time  $h_p$  of the distance between the moving adjacent spoons and pass through the main horizontal plane, the capacity of excavation for any moment in time is defined by the following:

$$Q_m(t) = \frac{n_c \cdot n_t}{60} \cdot \int_{\theta_1}^{\theta_2} A_j \left( \theta_m - \frac{\pi}{2} \right) \cdot \left[ R_p - R + x_c^j \left( \theta_m - \frac{\pi}{2} \right) \right] d\theta_m \quad (6)$$

where:

$$\theta_1 = \frac{2 \cdot \pi \cdot n_p}{60} \cdot \text{floor} \left[ \frac{t}{\Delta T} \right] + \theta_0 \cdot \frac{\pi}{180} \quad (7)$$

$$\theta_2 = \theta_1 + \frac{2 \cdot \pi \cdot n_p}{n_c \cdot n_t} \quad (8)$$

$$\Delta T = \frac{1}{z} = \frac{60}{n_c \cdot n_t} \quad (9)$$

In the expression (7),  $\theta_0$  represents the initial slewing angle and  $\text{floor}[x]$  is the largest integer equal to or less than  $x$ .

If the final angle of slewing  $\theta_f$  is known, the period for excavating a cutting on a certain slice can be calculated with the following expression:

$$t_f = \frac{10}{n_p \cdot n_c^2 \cdot n_t^2} \cdot [n_c \cdot n_t \cdot (\theta_f - \theta_0) - 360 \cdot n_p] \quad (10)$$

Additionally, using the Gaussian quadrature formula in 3 points, formula (6) becomes:

$$Q_m(t) = \frac{n_c \cdot n_t}{60} \cdot \frac{\theta_2 - \theta_1}{2} \cdot \sum_{i=0}^3 M_i \cdot f_1 \left( \frac{\theta_2 - \theta_1}{2} \cdot g_i + \frac{\theta_2 + \theta_1}{2} \right) \quad (11)$$

where:

$$f_1(x) = A_j \left( x - \frac{\pi}{2} \right) \cdot \left[ R_p - R + x_c^j \left( x - \frac{\pi}{2} \right) \right] \quad (12)$$

$$M_1 = M_3 = \frac{5}{9}; M_2 = \frac{8}{9} \quad (13)$$

$$-g_1 = g_3 = \sqrt{\frac{3}{5}}; g_2 = 0 \quad (14)$$

From the expression (11) it is visible that when the speed of the bucket wheel with spoons ( $n_t$ ) is kept at a constant value, then the momentary excavating capacity is directly proportional with the slewing speed ( $n_p$ ).

In the simulation of the excavation process, we will consider that the flow of material loaded onto the conveyor belt from the rotor excavator component is given by the following relation:

$$Q(t) = Q_m(t) - Q_n(t) \quad (15)$$

where:

$$Q_n(t) = k_0 \cdot |\theta_1| \quad (16)$$

is the lost flow in the load process, which is directly proportional to the pivot angle  $\theta_1$ .

The factor  $k_0$  from formula (16), is a random number from interval  $[0\% \dots 5\%] \cdot Q_m$ .

### 3. Simulation of the excavation process

The simulation of the excavation process is done in Matlab-Simulink and it is applied to excavator EsRc 1400.

The simulation program is based on a mathematical model as determined above.

In the simulation of the excavation process, the dynamic effects introduced by the induction machines that act both the port-cups wheel and the upper platform of the excavator are captured.

The bucket wheel is powered by an induction motor of 630 kW, and the upper platform of the excavator is powered by two 45 kW induction motors.

The induction motors used in the simulation are a squirrel - cage rotor.

The system which puts in motion the bucket wheel of the excavator consists of two sub-systems: the induction motor, the cone - cylinder four gear reducer and the two-speed gearbox.

The system putting in motion of the rotation mechanism of the upper platform consists of two induction motors and two cone-cylinder four gear reducers, identical, one for each motor.

The program for the simulation of the coal excavation process with the bucket wheel excavator is presented in Fig. 3.

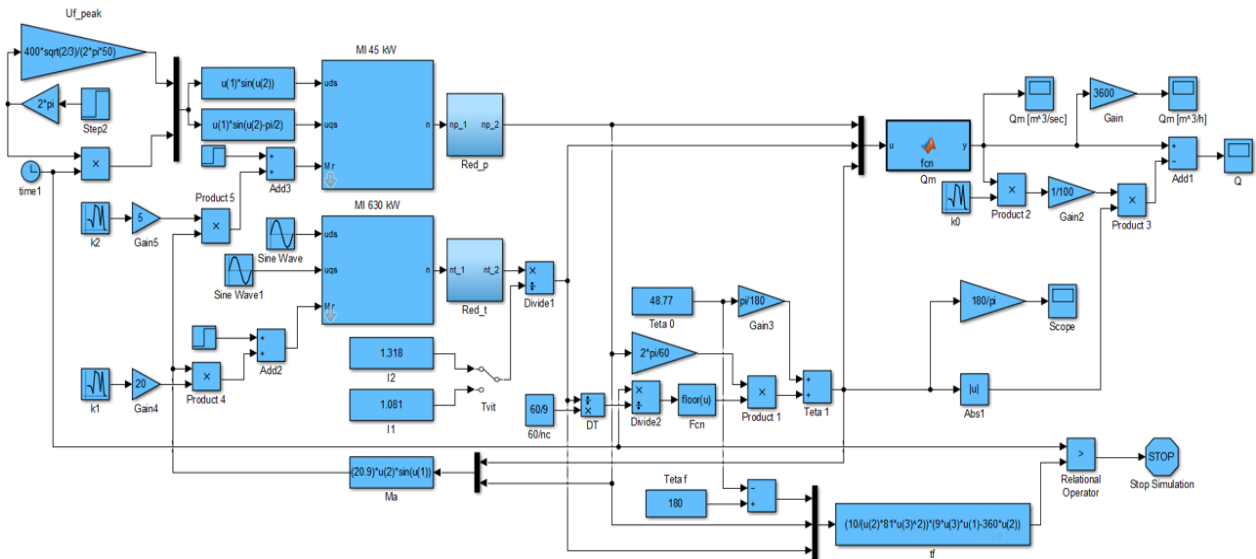


Fig. 3. The program for the simulation of excavation process

From Fig. 3, can be seen as within simulation the load torques are directly proportional to the excavation capacity.

To control the slewing speed, a scalar open-loop control system ( $U/f=ct$ ), is used in the simulation, Stoicuta (2012), Stoicuta (2016). The simulation of the excavation process is done in the case of starting under load of the induction motors. The simulation is done using the Dormand – Prince (ode45) numerical method, imposing a relative and absolute error of  $\varepsilon = 10^{-4}$ . In the simulation of the scalar open-loop control system, the frequency of the supply voltages of the induction motor of 45 kW, is 25 Hz.

In the analysis of the excavation process by numerical simulation, it will be analyzed 2 pivoting cycles defined by the following initial conditions:

- case 1:  $\Theta_0 = 53.09$  [degree] ;  $\Theta_f = 180$  [degree] ;
- case 2:  $\Theta_0 = 53.09$  [degree] ;  $\Theta_f = 138.77$  [degree] ;

The results of the simulation, for cases 1 and 2, in the conditions in which the drive system of the port- cup wheel is operating in stage 1, are shown in the the following figures:

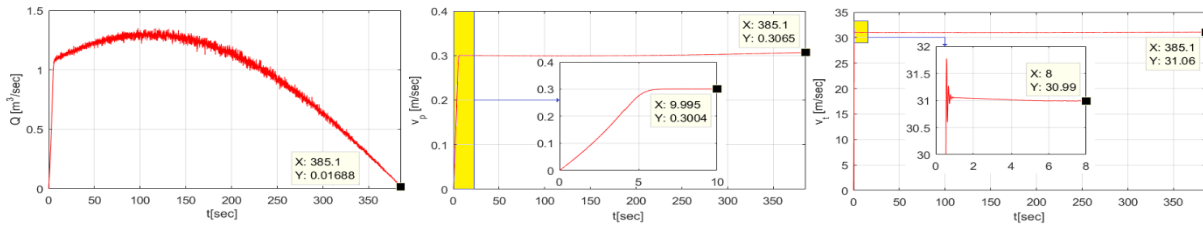


Fig. 4. Time variation of flow rate, pivoting speed and cutting speed case 1 - stage 1

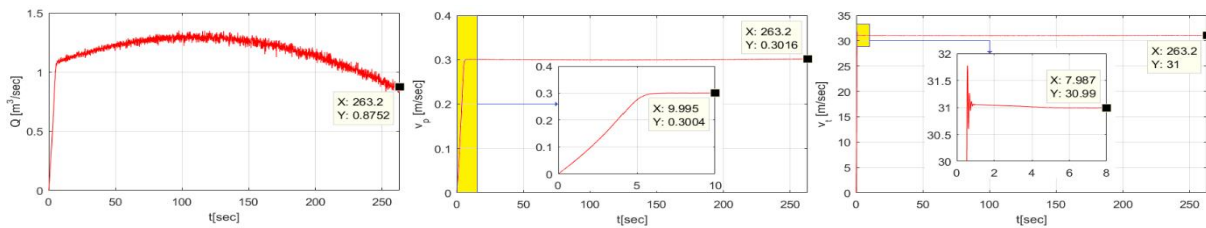


Fig. 5. Time variation of flow rate, pivoting speed and cutting speed case 2 - stage 1

From the figures presented above, it is noted that both in case 1 and 2, the pivoting and cutting speeds are maintained at a constant value throughout the pivot cycle. When the gear shifter in the port-cup wheel is operating in step 1, the steady-state cutting speed is about 31 [m/sec]. On the other hand, the stationary pivoting speeds for both analyzed cases are equal, having a value of approximately 0.3 [m/sec]. From Fig. 4 and Fig. 5, it can be seen that the duration of the pivot cycle for case 1 is approximately 385 [sec] and approximately 263 [sec] for case 2.

Regarding the flow rate of material loaded onto conveyor belt, in both cases analyzed, it is observed that it has a large variation in time, when the pivoting speed is constant.

In conclusion, the realization of relatively constant excavation flow, with as little variation possible within a pivot cycle, can be achieved by the following tandem:

- the total pivot angle is appropriately chosen (has a relatively small value);
- the required pivoting speed is calculated according to the pivot angle based on a control law, that has the role to compensate for variation in the flow time.

#### 4. Conclusions

From the researches made in this article, an original model of the flow resulting from the excavation process was obtained.

Based on the mathematical model of the flow resulting from the excavation process, a simulation program was developed in Matlab-Simulink, with which two pivoting cycles were analyzed, highlighting the main performance of the excavation process. Simulation of the excavation process was customized on the EsRc 1400 excavator. The simulation in Matlab-Simulink analyzed the excavation process in which the pivoting speed and the cutting speed are kept constant throughout the pivot cycle.

With the simulation programs presented in the article, the optimal values of the cutting parameters can be easily extracted, which allow for a constant amount of flow of material loaded onto the conveyor to be maintained over a certain pivot cycle.

## References

- Bosnjak, S., *Comments on Determination and analysis of the theoretical production of a bucket wheel excavator*, Arch.Min. Sci., vol. 60, no.1, pp. 283-301, 2015.
- Bosnjak, S., Petkovic, Z., Zrnic, N., Petric, S., *Mathematical modeling of dynamic processes of bucket wheel excavators*, Proceedings of the 5th Mathmod, Vienna, Austria, 8-10 February, 2006.
- Che Z.X., Chen, Y.L., *Determination and analysis of the theoretical production of a bucket wheel excavator*, Arch.Min. Sci., vol. 59, pp. 283-291, 2014.
- Dandea, D., Nan, M.S., *Design and simulation of a control system for the bucket wheel excavator*, Proceedings of the 12th International Conference on Applied Computer and Applied Computational Science (ACACOS'13), WSEAS, pp.117-123, Malaezia, 2013.
- Durst, W., Vogt, W., *Bucket Wheel Excavator*, Trans Tech Publications, Clausthal-Zellerfeld, 1988.
- Haliti, R., *Analysis of the theoretical capacity of a bucket wheel excavator in function of the geometric parameters of slice*, Journal of Environmental Science, Computer Science and Engineering & Technology, sec.C, vol.6, no.1, pp.8-17, 2016.
- Jevtic, B., Matausek, M., *Modeling of bucket wheel excavator: theory and experimental results*, Facta Universitatis, Series: Working and Living Environmental Protection, vol.2, no.4, pp.335-343, 2004
- Ladanyi, G., Sumegi, I., *Some issues of the technological design of bucket-wheel excavators*, Annals of the University of Petroșani, Mechanical Engineering, vol. 8, pp.63-72, 2006.
- Nan, M.S., *Parameters of the excavation process on rotor excavators*, Universitas Publishing House, Petrosani, 2007
- Nan, M.S., Andras, I., *Study of the working regime of the bucket wheel excavators in the conditions of the Romanian open pit lignite mines*, Proceedings of the 8th International Conference on Simulation, Modelling and Optimization (SMO'08), pp.83-88, 23-25 september, Spain, 2008.
- Pajer, G., Pfeifer, M., Kurth, F., *Tagebaugrosgeräte und Universalbagger*. VEB Verlag Technik, Berlin, 1971.
- Petrovic, G., Marinkovic, Z., Marinkovic, D., *Modeling and Simulation of the Operation of Excavator's Bucket Wheel Driving Mechanism*, Proceedings of 13th International Conference on Material Handling, Constructions and Logistics, 2006.
- Rasper, L., *The Bucket Wheel Excavator: Development - Design – Application*, Trans Tech Publications, Clausthal, 1975.
- Sharma, A., Szymanski, J., Anand, A., *A simulation analysis model of bucket wheel excavator-conveyor belt system for oil sand extraction and material handling*, International Journal of Mining and Mineral Engineering, vol.1, pp. 278-291, 2009.
- Stoicuta, O., *The modeling and simulation in Matlab-Simulink of the speed control systems of the induction motors*, Universitas Publishing House, Petroșani, 2012.
- Stoicuta, O., *The utilization of the S-Function block in simulation of the mathematical model of induction motor with iron loss*, Annals of the University of Petroșani, Electrical Engineering, vol. 18, pp.5-20, 2016.
- Stoicuta, O., *The utilization of the S-Function block in simulation of the Luenberger rotor flux observer for induction motors*, Annals of the University of Petroșani, Electrical Engineering, vol. 18, pp.31-46, 2016.
- Vetrov, Y.A., *Soil excavation with earthmoving machines* (in Russian), Mashinostroenie, Moscow, 1971.

# Researches on Wear and Reliability of Some Subassemblies and Spare Parts of Technological Equipments

Vlad Alexandru Florea<sup>a\*</sup>

<sup>a</sup> University of Petrosani, 20 University street, 332006, Petrosani, Romania

---

## Abstract

In practice the need to know how to behavior different components of technological equipment under severe abrasive wear conditions, especially abrasive wear. Thus, various subassemblies and spare parts can be listed which through their high specific consumption, cause high production costs and lead to a low overall profitability, The paper presents the results of researches on the wear and reliability of some subassemblies and spare parts of the mining technological equipment. The research pursued the evolution of wear in time of the various subassemblies and spare parts of the mining equipment as well as determination of their reliability based on the data obtained in the production practice.

*Keywords:* abrasive wear, reliability, tools, teeth, technological equipment

---

## 1. INTRODUCTION

The complex friction-wear phenomenon of the technological equipment subassemblies is a research objective for determining wear capacity of other materials on them, such as the dislocated, transported or processed sterile rocks as well as determining their reliability. Mining shearers, coal screens in preparation, excavators and loaders in quarries, operate under sterile rocks, coal etc. conditions is subject to abrasive wear and change in reliability

Vibrating screens type SCC III from preparations, which take up the coal to achieve removal of material particles less than 0.8 mm, have a number of subassemblies, such as screening surfaces (fig. 1), the troughs, the loading funnel and the basic support of the screen, subjected to excessive wear.

The difference in behavior between different subassemblies of the same machine can be appreciated only after a reliability analysis, because if you take example of the screen, it found that while screening surface has a reliability of 4.8 %, after 100 hours, the trough has a reliability of 31.3 %, for the same useful life.



Fig.1. Worn screening surface

Rocks cutting and dislocation tools (fig. 2) are reinforced with hard alloy inserts which ensure hardness, modulus of elasticity and thermal heat transfer.

---

\* Corresponding author. Tel.: 0040722348000.

E-mail address: VladFlorea@upet.ro.

The variation of the specific wear  $\Psi_A$  of the tools, depending on rocks abrasion (fig. 3) experimentally established, can determine the degree of wear of the tools, over time, depending on this property. This is important because it has been found that the value of the tools for cutting and dislocation the rocks sometimes represents 14 % of the production costs. Alongside the shearer tools, the excavator teeth can be exemplified (fig. 4) that supporting significant wear and cause, the same measure and for the same reasons, the negative economic effects.



Fig. 2. Worn shearer tools CMR 4

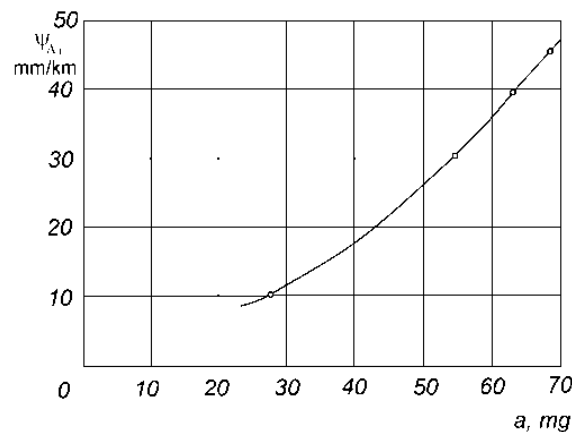


Fig. 3. Variation of the specific wear of the shearer tools depending on rocks abrasion



Fig. 4. Worn excavator teeth

Knowing reliability and practical aspects of these problems refers to the establishment of the theoretical distribution laws that can shape the mechanical phenomena of failure, including wear, and to the ways to improve the behaviour in time of different subassemblies of the technological equipment.

## 2. Reliability analysis of subassemblies „trough” of the screen type SCC III

Experimental data used in the analysis:

- $T_f$  time between failures (table 1) for  $n=26$  events (in increasing order);
- $T_{rem}$ , time to repair of trough (also in increasing order).

Based on data from table 1, the mean value of operation times, calculated between failures is:

$$M[t] = \sum_{i=1}^k t_i \cdot f(t_i) = 59,53 + 49,61 + 33,06 + 36,33 = 178,53 \text{ [hours]} \quad (1)$$

And the value of mean time to repair is:

$$MTR = \frac{\sum_{i=1}^{26} T_{rem}}{n} = \frac{1730}{26} = 66,54 \text{ [min]} \quad (2)$$

Table 1 Values of time between failures and time to repair of trough

$T_f$	7	7	14	14	21	49	56	56	56	63
[hours]	63	70	91	112	112	133	154	154	175	203
	224	231	287	462	511	987				
$T_{rem}$	20	30	45	50	50	50	50	50	60	60
[minute]	70	70	70	70	70	70	70	80	80	80
	80	80	90	90	90	105				

The time interval  $\Delta t$  needed to determine the relative frequency  $f(t_i)$  is calculated with the Sturges relationship:

$$\Delta t = \frac{t_{\max} - t_{\min}}{1 + 3,322 \cdot \lg n} = \frac{987 - 7}{1 + 3,322 \cdot \lg 26} = 171,9 \text{ [hours]} \quad (3)$$

where,  $t_{\max}$  and  $t_{\min}$  are the maximum and minimum limits of operating times and  $n$  represents the number of events

Is chosen  $\Delta t = 172$  [hours], resulting  $K=6$  time intervals.

For the exponential distribution law the failures rate is

$$\lambda = \frac{1}{M[t]} = \frac{1}{178,53} = 0,005601 \text{ [hours}^{-1}] \quad (4)$$

Using the obtained data, the relative frequencies  $f(t_i)$ , cumulative frequencies  $F_c(t_i)$  and functions  $F(t_i)$  can be determined (table2).

Table 2 Exponential distribution function and the distance “d” for trough

Nr. int.	Interval size $\Delta t$	Average value $t_i$	Number of failures $n_i$	Relative frequency $f(t_i)$	Cumulative frequency $F_c(t_i)$	Distribution function $F(t_i)$	d
1	0÷172	86	18	0,6923	0,6923	0,3822	0,31
2	172÷344	258	5	0,1923	0,8846	0,7643	0,12
3	344÷516	430	2	0,0769	0,9615	0,91	0,052
4	516÷688	602	-	-	0,9615	0,9657	0,004
5	688÷860	774	-	-	0,9615	0,9869	0,025
6	860÷1032	946	1	0,0384	0,9999	0,995	0,005
$n=26$							

The validity of the exponential distribution law is tested:

$$F(t_i) = 1 - e^{-\lambda \cdot t_i} \quad (5)$$

The value of the distribution function obtained (table 2) allows the calculation of the distance “d” between the theoretical and experimental distribution function. It is found that this law does not validate, according to the Kolmogorov concordance test, because:

$$d_{\max} = 0,31 > \frac{1,36}{\sqrt{n}} = \frac{1,36}{\sqrt{26}} = 0,2667 \quad (6)$$

It is necessary to choose another law, for example the Weibull distribution law. The values of the Weibull distribution function, presented in table 3, correspond to the parameters calculated using the relations:

$$a_1 = \frac{\sum_{i=1}^k \ln t_i \sum_{i=1}^k Y_i \cdot \ln t_i - \sum_{i=1}^k Y_i \sum_{i=1}^k \ln^2 t_i}{\sum_{i=1}^k \ln t_i^2 - k \cdot \sum_{i=1}^k \ln^2 t_i} = \frac{35,972 \cdot 42,764 - 6,693 \cdot 219,604}{35,972^2 - 6 \cdot 219,604} = -2,8976 \quad (7)$$

where:

$$Y_i = \ln \ln \frac{1}{1 - F_c(t_i)} \quad (8)$$

Result:

$$\lambda = e^{a_1} = e^{-2,8976} = 0,05557; \quad (9)$$

$$a_2 = \frac{\sum_{i=1}^k \ln t_i \sum_{i=1}^k Y_i - k \sum_{i=1}^k Y_i \cdot \ln t_i}{\sum_{i=1}^k \ln t_i^2 - k \cdot \sum_{i=1}^k \ln^2 t_i} = \frac{35,972 \cdot 6,693 - 6 \cdot 42,764}{35,972^2 - 6 \cdot 219,604} = 0,6694 \quad (10)$$

$$\beta = a_2 = 0,6694 \quad (11)$$



The mean time between failures (MTBF) result from the relation:

$$MTBF = \frac{\Gamma(1/\beta+1)}{\lambda^{1/\beta}} = \frac{1,344}{0,05557^{1/0,6694}} = 107,2 \text{ [ore]} \quad (12)$$

It is found that the Weibull distribution law is validated according to the Kolmogorov concordance test because:

$$d_{\max} = 0,11 < \frac{1,36}{\sqrt{n}} = \frac{1,36}{\sqrt{26}} = 0,2667 \quad (13)$$

In the case of Weibull biparametric model the expression of reliability is:

$$R(t_i) = e^{-\lambda \cdot t_i^\beta} \quad (14)$$

Table 3 Values of the Weibull distribution function and the distance "d" for trough

Nr. int.	Average value $t_i$	Cumulative frequency $F_c(t_i)$	$Y_i$	$\ln t_i$	$\ln^2 t_i$	$Y_i \cdot \ln t_i$	Distribution function $F(t_i)$	d
1.	86	0,6923	0,164	4,454	19,841	0,730	0,650	0,08
2.	258	0,8846	0,769	5,552	30,835	4,269	0,885	0,11
3.	430	0,9615	1,180	6,063	36,769	7,154	0,952	0,009
4.	602	0,9615	1,180	6,400	40,963	7,552	0,977	0,016
5.	774	0,9615	1,180	6,651	44,243	7,848	0,988	0,027
6.	946	0,9999	2,220	6,852	46,953	15,211	0,994	0,059
$\Sigma$			6,693	35,972	219,604	42,764		

The reliability values for the Weibull distribution, for different operating times, of the trough subassembly are shown in table 4 and represented in figure 5.

Table 4 Reliability variation depending on the time for trough subassembly

$t$ [hours]	50	100	150	200	250	300	350
$R(t)$ [%]	0,479	0,313	0,219	0,159	0,119	0,090	0,070
$t$ [hours]	400	500	600	700	800	900	1000
$R(t)$ [%]	0,055	0,034	0,022	0,015	0,010	0,007	0,004

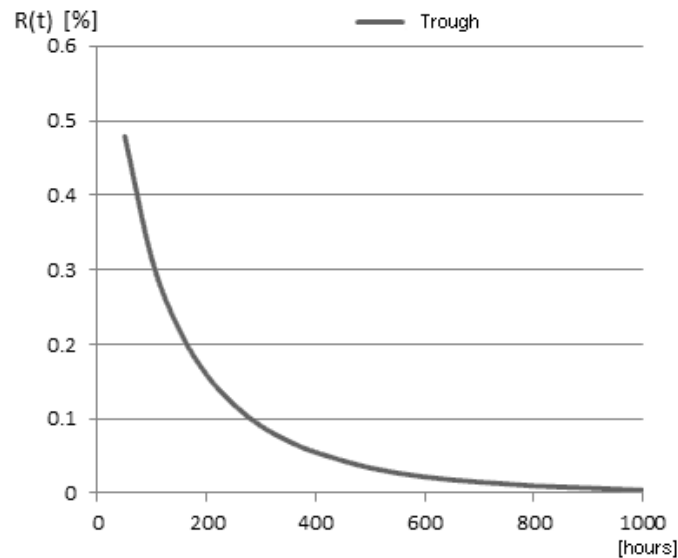


Fig. 5. Reliability variation of trough of the vibrating screens

### 3. Evolution wear to cup teeth of the frontal loaders and solutions to increase their lifetime

Equipping basalt quarries with dislocation and frontal loading machine on tires type Volvo L 220 E allows for the following operations

- loading crushed stone in trucks for delivery;
- transportation of crushed stone to the temporary deposit;
- feeding with broken stone of the crushing the secondary flow;
- cleaning and arranging the access ways both on the crushing platform and on the working front.

The analysis of the behaviour of subassemblies that are subject to excessive wear on Volvo L 220 E machines to point out the need for frequently replacement of some of them, especially the cup teeth (fig. 6 a). The abrasive wear of the loader teeth in the production of aggregates from basalt rocks, is mainly, determined by the dimensional changes and the weight loss at the active surfaces (fig. 6 b).

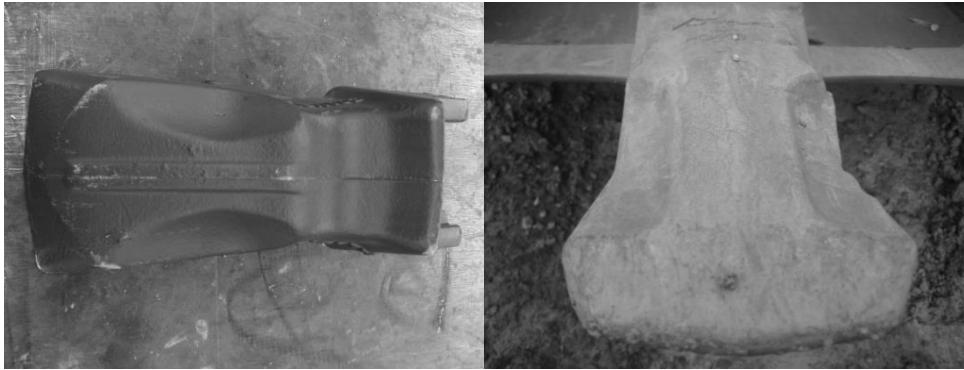


Fig. 6. Cup tooth for the Volvo equipment: a-new teeth; b-worn teeth

Determining how cup teeth wear evolve (fig. 7) have led to the necessity of finding solutions to increase their lifetime.

The methodology for improving the technical-economic characteristics of the cup teeth has as its starting point the precise setting of their chemical composition (table 5) and hardness. The chemical composition of the cast tooth, determined experimentally, is within the mark of alloy steel G45CrNiMo4, in accordance with SR EN 1027-1.

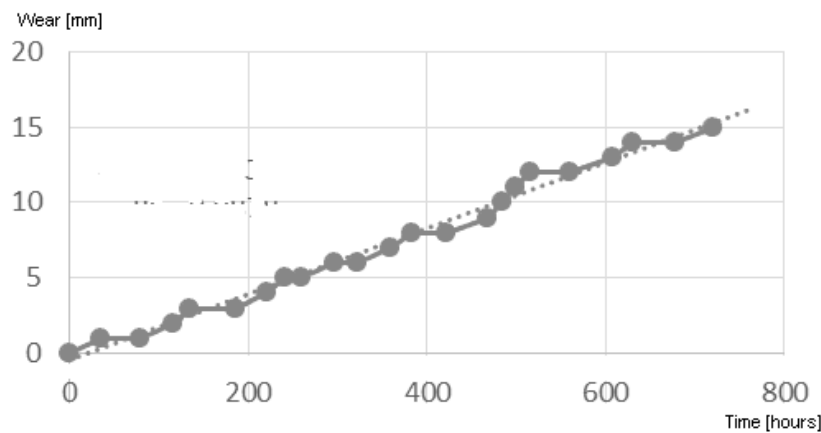


Fig. 7. Evolutions of cup teeth wear

Table 5 Chemical composition of the cup cast tooth

Cup tooth material	Chemical composition							
	[%]							
	C	Si	Mn	P	S	Cr	Ni	Mo
Alloy steel G45CrNiMo4	0,45	0,26	0,80	0,007	0,06	1,00	0,50	0,15

Sclerometric investigations to be effected on the two teeth, in transverse section in five zones randomly selected (table 6), and conversion  $HRC=f(HV 10)$  has achieved in accordance with DIN 50-150.

Table 6 Cup teeth hardness

Number of tooth	Hardness									
	HV10	HRC	HV10	HRC	HV10	HRC	HV10	HRC	HV10	HRC
1	425	43	437	44	464	46	458	46	466	47
2	421	42	442	45	473	46,5	462	47	459	46

Elaboration of self-protection system against tooth wear (fig. 8) can be done in different mode, depending on active zone position namely:

- the active tooth edge, protects with compact layer;
- the active surfaces, protects with rhomboidal systems.

Manual electrically welded load with electrodes coated containing the alloys of the type Cr25%-4%W-1%Ti-V can provide good abrasion resistance and allows reconditioning of used teeth, without demounting them from equipment, by using the existing equip in quarries.



Fig. 8. Wear self-protection system

#### 4. Conclusions

Operating conditions of the technological equipment, in general and due to mining in particular, influences their useful life especially the negative effects of abrasive wear. In this context it is necessary to create the experimental data base regarding the wear and the useful times achieved in the practice as well as the elaboration of the reliability analyses. Evaluation of reliability indicators can lead to the development of specific methodologies for rehabilitation of technological equipment which in turn can lead to savings and increased profitability in production processes.

#### References

- Binchiciu, H., Surgean, I., s.a., *Încărcarea prin sudare cu arcul electric*, Editura Tehnică, Bucuresti, (1992);  
Florea, V.A., *Fiabilitatea și mentenanța produselor – îndrumător de laborator*, Editura Universitas, Petroșani, (2011);  
Iovanas, R., Iovanas, D.M., *Recondiționarea și remanierea produselor sudate*, Editura Universității Transilvania din Brașov, (2006);  
Todorescu, A., *Proprietățile rocilor*, Editura Tehnică, București, (1984).

# The Use of Quality Function Deployment Method in the Transport Activity

Gabriel Praporgescu<sup>a\*</sup>

<sup>a</sup>University of Petroșani, University Str., 332006, Petroșani, Romania

---

## Abstract

Quality planning represents one of the fundamental principles of quality management. Through planning, the objectives of undertaking the quality together with the human, financial and material resources necessary for obtaining them are established. The operational planning of quality relates to both external issues – customer identification and establishing their needs and internal issues – transposing the customer’s requirements into quality characteristics of the product together with developing processes that ensure the achievement of these characteristics.

*Keywords: Quality, transport, quality functions*

---

## 1. Introduction

The basic principles and fundamental objectives of a company, regarding quality, make up the strategic planning of quality, which comprises the following steps:

- Quality diagnosis;
- Forecast analysis;
- Establishing the fundamental objectives in quality;
- Necessary resources determination for attaining these objectives;
- Establishing the optimal actions, through the strategic plan of. (Boroiu, 2010, Boroiu, 2014, Sivasamy et al., 2015, Tsoukalidis et al., 2009)

Operational planning of quality in the transport field relates to both external issues (customer’s identification and establishing their needs) and internal issues (transposing the customer’s requirements into quality characteristics of the product together with developing processes that ensure the achievement of these characteristics).

## 2. Transport Company Activity

The transport services execution by DMW Logistic Company is made possible through the management and execution of the activities by qualified employees, with a large skill regarding this domain and obeying all the regulations applicable in this field of activity. The road transport services are offered to some customers from different counties of the country, but also to some external customers. The company implemented the quality management system in order to keep up with the customer’s requirements and existing regulations in this field of work. In this way, between the DMW Logistic company representatives and customers, trust, seriousness and promptitude based relationships were established.

### a) Identifying the problem types

In 21.02.-16.03.2017 period, in which the activity of DMW Logistic Company was analysed, a series of causes were identified, which led to exceeding the delivery times of the finite materials to customers as well as exceeding the arrival terms of the gross material coming from the customers. At a first glance, the management reached to the conclusion that the main factor is the personnel inside the society, namely the drivers; regarding this, it was decided to make an internal audit for identifying and implementation of the measures which are needed in order to eliminate the quality deficiencies. As a result, the following conclusions were centralized (table 1).

---

\* Corresponding author. Tel.: +0724708876.  
E-mail address: gpraporgescu@gmail.com.

Table 1. Conclusions resulting from the internal audit.

Criterion	Questions
Chronicity	Usual problems: - indiscipline and carelessness of the personnel; - obsolescence of the vehicles; - improperly externalized inspections; - difficulties of orientation for the drivers regarding the foreign customers.
Importance	It is targeted the personnel problems elimination
Duration	It is proposed a 30 days
Measure of potential impact	It is desired: • keeping the old customers; • bringing new customers; • improving the satisfaction degree of the customers; • making the employees loyal.
Urgency	The results during a 3 month period are being considered
Risk	The results can be different from the desired ones
Possible resistance to change	In the first phase, only the problems which do not face resistance will be addressed
The success of the action	The most successful actions were chosen
Measurement	Consists in questionnaires sent to customers.

The major problem that was identified is: endowment with performant means of transport. The team produces the mission: In the next period of time it is desired the acquisition of performant means of transport and improving the number of customers by 5%.

#### b) Measurement

The measurement was made based on the feed-back received from the drivers after each route by having them completing a form with every problem they had during the transport. From these forms, the team extracted and processed the data based on which they determined the house of quality (Quality Function Deployment method – QFD).

### 3. Quality Function Deployment method (QFD).

#### 3.1. General aspects. (Cristiano, et a., 2001, Ghobadian and Terry, 1995, Lockamy and Khurana, 1995, Petrescu, 2015)

The base principle of this method is the fulfilling of the requirement of customers, in every step of the provided product (service). All the activities of evolving the product are seen through the eyes of the customers, not of the producer. In this way, QFD is the methodology which allows the transformation of beneficiary's requirements in quality characteristics of the service.

QFD is a group working method, the activity being developed through brainstorming meetings together with Decision making individuals from all the departments of the company organization (marketing, production, quality etc.).

The characteristic of the method is that the fulfilling of the quality requirements is wanted in every phase of the production process. All the product evolving activities of the product are seen from the customer's perspective, not from the producer one. The start point in making new products, or the improvement of the existing ones should be the identification and evaluation of the customer's requirements. The customer's requirements are materialized in specifications which will be made accordingly for each phase of the process, ensuring the conditions for creating a satisfactory product (service) for the customer.

For applying the method, a diagram named "house of quality" is used, which is a table with two entries in which the rows are represented by the customer's requirements and the columns by the quality characteristics.

The instrument of the QFD method is a diagram called "House of Quality" respectively "La maison de la qualite" in French. The central part of the diagram has the shape of a table with two entries: on rows the requirements of the customers and the importance of them are mentioned and on columns the quality characteristics through which the requirements will be fulfilled. On top of the quality characteristics the "roof of quality house" is realized – a triangular matrix which makes the correlation diagram for the quality characteristics, which permits the identification of the opposite characteristics in order to solve the conflict situations. At the intersection of the rows with columns it is highlighted the correspondence between the customer's requirements and the quality characteristics of the product. The product between the importance of the requirement and the degree of correlation between the requirement and characteristic is computed in each cell of the matrix.

The sum of these values on column represents the absolute importance of each characteristic for fulfilling the customer's requirements. In this way, the characteristics can be ranked (the relative importance is determined), in order to establish the action priorities for ensuring the quality characteristics.

It should be mentioned that this is just the first phase from the more complex methodology QFD which comprises a continuous flow of information, starting with the customer's requirements until the operating instructions of them at the workplace (Boroiu, 2014). The whole QFD methodology comprises four phases (fig. 1):

1 – product planning (largely, services are considered products);

- *inputs*: organization customer's requirements;
- *outputs*: specifications or characteristics of the product.

- 2 – design of the components;
  - *inputs*: specifications or characteristics of the product;
  - *outputs*: specifications or characteristics of the component parts of the product.
- 3 – process planning;
  - *inputs*: specifications or characteristics of the component parts of the product;
  - *outputs*: specifications or characteristics of the technological process of production.
- 4 – production planning.
  - *inputs*: specifications or characteristics of the technological process of production;
  - *outputs*: specifications or characteristics of the production process.

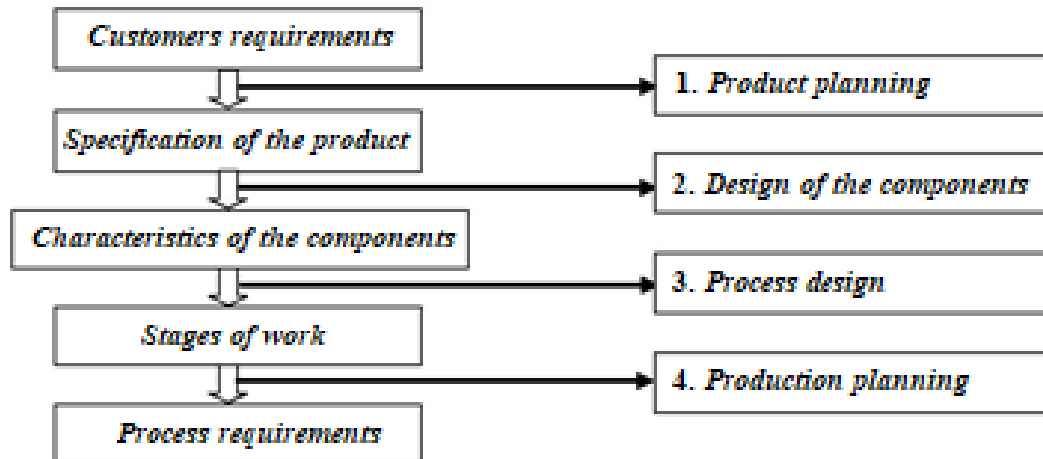


Fig. 1. QFD phases succession. (Boroiu, 2014).

For the application of the method the following steps should be performed:

- determination of the customer's requirements and their weight function of the importance that it represents for them;
- establishing the quality characteristics; the importance of the quality characteristics is established as a total score by multiplying the importance coefficient of the customer's requirements with the score given to these characteristics; establishing the quality characteristics value which should be obtained by assessing their degree of difficulty. At the same time, it is determined the desirable variation sense of the characteristic value: growth (↑), decrease (↓), indifferent (o);
- interaction evaluation – the correlations between the quality characteristics are studied, the results being noted in the matrix of correlations which can be found near the “roof of the quality house”. This correlation can be positive or negative, but more levels of correlation can be established: strongly positive, medium, strongly negative, or strongly positive, positive, indifferent (no correlation) negative, strongly negative;
- the comparison analysis of the planned product with the concurrence product is realized from two points of view: from the customer point of view and by comparing the technical level of the product with the concurrent product.

This methodology can be applied to the entire cycle of making a product, but it is not finished with this activity. For quality improvement, there is a continuous retaking of the methodology, this being called *the helix of never-ending improvement* through which the cycle of Deming is applied successively (*Plan-Do-Check-Act*) and QFD method.

This continuous quality improvement is known as quality helix or “Juran's helix”, because we can find all the steps of making the product along it.

The application of QFD method imposes the crossing of an algorithm which implies the usage of the main techniques and instruments used in quality management: customer forms, benchmarking, brainstorming, weighted vote, relationships diagram, correlation diagram etc.

### 3.2. Using Quality Function Deployment Method

The first step is finding the customer's desires and their importance on a scale from 1 to 5. In this aspect, each potential customer was sent a form through e-mail.

At the same time, the form was implying also the evaluation of DMW Logistic services in comparison with concurrent companies. There were received answers from approximately 45% from those asked and the team which was assigned with the solving of the quality problem that appeared made the following table (table 2).

The comparison analysis of the transport services used at DMW Logistic Company is presented in table 3. It can be seen that from the professional point of view (technical endowment and professional abilities), that the own transport company DMW Logistic is superior with respect to the concurrence. On the other hand, from the point of view of performant technical means of transport endowment and appropriate cargo packing, the company is on the same level or under other companies that offer transport services.

Table 2. Customer evaluation of the own transport company in comparison with the concurrence

Customer requirement	Requirement importance index				
	DMW Logistic	CARTRANS SA	SAFE TRANS	TRANSIBO SA	M.E.A. SRL
1. Performant transport means endowment	4	4	4	3	3
2. Respecting the taking/delivery terms	5	3	3	4	4
3. Ensuring „just in time” service	4	2	4	3	3
4. Ensuring „door to door” service	5	3	3	4	4
5. Appropriate cargo pack	3	3	5	4	2
6. Product safety	4	3	2	3	3
7. Good prices	5	2	3	4	4

The comparison analysis of the transport service made by the own company (DMW Logistic) with the concurrent transport companies is made from two points of view: from the customer point of view and by comparing their technical level with the concurrence one.

Table 3. Comparison analysis of transport services at SC ZINCHERIA SA Company.

Customer requirement	Comparison analysis									
	1. DMW Logistic	2. CARTRANS SA	3. SAFE TRANS	4. TRANSIBO SA	5. M.E.A. SRL					
						1	2	3	4	5
1. Means endowment ...	4	4	4	3	3					
2. Respecting deadlines	5	3	3	4	4					
3. „Just in time” service	4	2	4	3	3					
4. „Door to door” service	5	3	3	4	4					
5. Appropriate packing	3	3	5	4	2					
6. Product safety	4	3	2	3	3					
7. Good prices	5	2	3	4	4					
8. Seriousness and kindness	3	2	2	3	3					

*Identification of the quality characteristics and their objectives.* For the quality characteristics to be identified, a multidisciplinary team is put together in which together with DMW Logistic company employees it is advised to take part also representatives of Bordignon Group. It is mentioned the preferable sense of variation of characteristic value, namely: growth (↑), decrease (↓), indifferent (o) (table 4).

Table 4. Quality characteristics and their objectives.

Quality characteristic	Objective
1. Qualified, authorized and periodically trained personnel	o
2. Technical endowment and fleet monitoring system updating	o
3. Communication training for the personnel	↑
4. Flexible work hours, adaptable to requests	↑
5. Waiting room built for customers	o
6. Partnership with packing supplying company	o
7. Housing the customer and the efficiency of communication with him	↑
8. Display of information regarding the offered services	o
9. Personnel objectiveness	o
10. Transport duration (including zinc coating services) as low as possible	↓

*Putting together the correlation matrix between quality characteristics.* This matrix will be the “roof of the quality house”. There are used five levels of correlation, with the following symbols:

- strongly positive (++)
- positive (+)
- no correlation (o)
- strongly negative (- -)
- negative (-)

These levels of correlation show the measure through which quality characteristics are supporting each other or are in conflict. It is determined that generally there are positive correlations or no correlations at all, and the poorly negative that exists are generated mainly by the concurrence of consuming some limited financial funds inside the same company.



*Self-evaluation of the organization regarding the concurrence.* The technical evaluation of the quality characteristics is made similarly with the evaluation made by customers taking into account the concurrence, only this time, the input data is not offered by customers, but by the technical leadership of the organization. The concurrence organization that obtains a superior score for one of the characteristics becomes the benchmark level for DMW Logistic company, the benchmark level becoming an quality objective for it.

*Establishing the “customer requirements” – “quality characteristics” relationship matrix.* This matrix (fig. 2) offers a mechanism of analysing the mode through which a quality characteristic helps fulfilling a customer requirement. A score that weights more the results can be used: 0 = no relation; 1 = poor relation; 3 = medium relation; 5 = very good relation. An index is given to each relationship and below, with bold characters it is noted the product between the importance of the requirement and the relationship index between that quality characteristic and requirement.

The absolute importance of each quality characteristic is computed by summing, on columns, the obtained products and the relative importance (priority order) of the quality characteristic is obtained by ranking from greatest to smallest they obtained values (fig. 2).

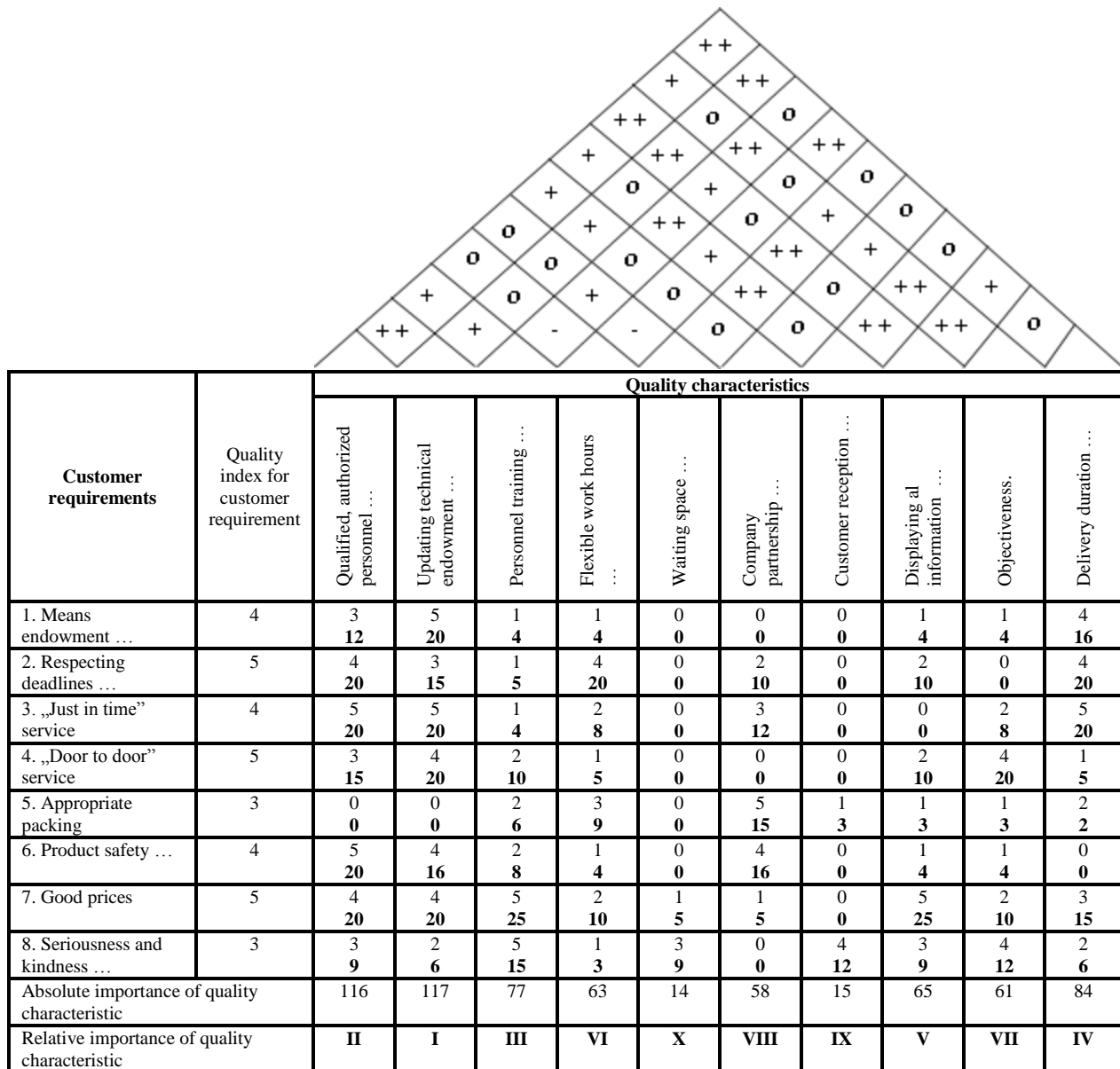


Fig. 2. Quality house.

*Results interpretation.* After the ranking of the quality characteristics, it can be seen that for fulfilling the customer requirements, updating the technical endowment and employee’s professionalism have priority. It can be seen that special communication abilities are necessary from the personnel point of view, which is in accordance with the position occupied by the customer in the new concept of quality management.

Also, promoting a flexible work schedule, customer reception and communication efficiency with the customer, waiting room for customers, personnel objectiveness, are quality characteristics that are important for fulfilling the requirements of the customer.

For attaining the proposed objective – to offer highly qualitative services in comparison with the concurrence – DMW Logistic company will have to act in order to obtain performances with quality characteristics determined according to the hierarchy obtained through QFD method.

For reaching these objectives, the correlations identified in the “roof of the quality house” will be taken into account, in order for the development of the quality function to ensure high competitiveness in efficiency conditions. In this way, it is usually seen that we have strongly positive and positive correlations between the quality characteristics of the transport service offered by the own company (and not by other companies) and also characteristics with no correlation and very few characteristics with negative correlation.

#### 4. Conclusions

For attaining the quality objectives of the transport activities offered by DMW Logistic Company, there were used the QFD method (Quality Function Deployment).

The conclusion that was reached is that for the fulfilment of the quality requirements of the customers it would be necessary to take action towards endowing the auto park (endowment of the existing park with modern equipment or replacing the means that are old), but also towards the personnel which does the transport activity (incentives, taking part into specialization courses, periodic training towards customer interaction).

All these actions lead to a more efficient transport activity, on which the production rate of the DMW Logistic Company is depending. This can take place by reduced consumption for usage and maintenance of the transport means, through getting new customers, by reducing the delivery times and times for manipulating materials. In this way, the objective desired by the company can be reached, that is applying a total quality management and obtaining performance in the offered services quality field.

The man in charge with quality control ensures the logic tools used for verifying the fulfilment of the customer with respect to new market information acquiring requirements. After the data were analysed “Correction actions” or “Preventing actions” can be identified. These documents are annexed to “The Business Plan”, an important document which is emitted annually by the administration. Actually, taking into consideration the market condition and the re-evaluation of the company’s politics, the fundamental strategic objectives are identified together with the key success factors.

The final result of the analysis is indicated in the “Annual Business Plan” as a matter of improving objectives of the company. For each objective an operative planning is made for its correct management by establishing tempos, responsibilities, the intervals of checking the objective values etc.

#### References

- Boroiu, A., *Instrumente statistice utilizate în managementul calității*, Editura Universității din Pitești, (2010).
- Boroiu, A.A., *Îmbunătățirea calității serviciilor de mentenanță prin utilizarea metodei QFD*, Referat Universitatea POLITEHNICA București, (2014).
- Cristiano, J. Liker, J., C. White, C., *Key Factors in the successful application of quality function deployment (QFD)*, IEEE Transactions on Engineering Management, Vol. 48, No. 1, pg. 81-95, February (2001).
- Ghobadian, A, Terry, A.J., *How Alitalia improves service quality through quality function deployment*, Managing service quality, 5,5; ABI/INFORM Collection, pg.25, (1995).
- Lockamy, A., A. Khurana, A., *Quality Function Deployment: A Case Study*, Production and Inventory Management Journal, Second Quarter;; 36,2; ABI/INFORM Collection, pg.56, (1995)
- Petrescu, R.V., *Calitatea transporturilor*, Note ce curs, Universitatea POLITEHNICA București, (2015).
- Sivasamy, K., Arumugam, C., Devadasan, S.R., Muruges, R., Thilak, V.M.M., *Advanced models of quality function deployment: a literature review*, pg. 1399–1414, Published online: 5 May 2015, Springer Science+Business Media Dordrecht (2015).
- Tsoukalidis, I., Karasavoglou, A., Mandilas, A., Valsamidis, St., *Application of Quality Function Deployment on an Alternative Transportation System (Paratransit System)*, European Research Studies, Volume XII, Issue (2) (2009).

## Quality of Equipment Used in the Mining Industry

Cristian Ilioni<sup>a\*</sup>

<sup>a</sup> University of Petrosani, 20 University street, 332006, Petrosani, Romania

---

### Abstract

In the first part of the research, the five concepts used in industrial practice, quality, reliability, maintainability, maintenance and availability are defined, the definitions of which result in the structural links between them, all of which equate to the characterization of the functionality of a product.

For defining the concept of quality, it is absolutely necessary to detail the four elements that have been defined. The complexity of the concept of reliability is highlighted, which, in a complete presentation, should include technical, operational, commercial and management approaches.

The factors that contribute to defining the quality of a mining equipment or equipment are highlighted, given the particular circumstances in which they are exploited.

The cause-effect diagram, or the Ishikawa diagram, is a complex way of analyzing a product's quality.

The method is based on the detailed determination of the causes that may lead to the appearance of a defect, so that the best possible measures can be taken to remedy it or even prevent it from occurring.

*Keywords:* quality, reliability, maintainability;

---

### 1. Introduction

The concept of product **quality**, having a complex character, requires the consideration of a large number of concepts.

In relation to the nature and effect they have in the use process, the quality characteristics are grouped into the following typologies: technical, availability, of a general, economic social character.

The concept of **reliability** can be defined qualitatively and quantitatively.

From a qualitative point of view, reliability is the ability of a system to operate without failures within a certain amount of time under given conditions. In other words, but expressing the same essence, in qualitative terms, reliability is defined as the set of qualitative characteristics of a product (technical system), which determines its ability to perform its specific function (preservation of performance) under prescribed conditions, over a specified period of time. By its qualitative characteristics, the product is the material carrier of a service it performs. In this respect, it can be said that reliability is quality over time.

From a quantitative point of view, reliability is the characteristic of a system defined by the likelihood that it will perform its specified function within a given timeframe and under given conditions. Therefore, for quantitative expression of reliability, elements of probability theory and mathematical statistics are used, as the failure and repair mechanism is not subject to deterministic laws.

The numeric value of a reliability parameter for an item, device, product, or system is called a reliability indicator.

**Maintenance** is the ability of a system to operate under conditions of operation, to be maintained or restored to perform its specified function when maintenance and repairs are carried out under specified conditions with good stability. Like the notion of reliability, maintainability can be defined from two points of view: qualitative and quantitative.

---

\* Corresponding author. Tel.: 0040764408627.

E-mail address: c\_ilioni@yahoo.com

From a qualitative point of view, maintenance is the ability of the system to be supervised, maintained and repaired over a certain period of time and certain given conditions. In quantitative terms, the maintenance of a system is the probability of returning it to the operating state, within specified time limits and under given conditions, when a defect occurs.

Maintenance is the set of all associated technical and organizational actions that are performed to maintain or restore a system in the state of performing its specified functions.

**Availability** is the probability that a technical system will perform its specified function at a given time or within a given timeframe as a result of the combined effects of reliability, maintainability and maintenance.

Availability is the feature of systems that users perceive directly. It is the most complex and appropriate measure of the quality of the technical systems during their operation, as it is the consequence of both the probability of good functioning expressed in reliability and the probability of restoring the state of good functioning expressed in terms of maintenance.

## **2. The main links between reliability and maintainability**

After analysing the contents of the concepts of reliability and maintainability, a series of assumptions were made that show the link between these two:

- It is noted at the outset that reliability and maintainability studies are carried out in parallel, at different stages of product promotion, namely in the development of technical documentation, execution, reception, transport, operation and renewal of the product, all of which are viewed from the point of view technical and economic view;
- Maintenance operations of whatever nature are related to the random character life of the elements, hence the reliability characteristics of the elements: the reliability function, the average running time to the first failure or between two failures, rate or instantaneous failure intensity;
- The frequency of corrective maintenance operations depends on the failure rate or severity or the risk of failure. In addition, it can be said that corrective maintenance, by reducing the failure rate, leads to improved reliability;
- Depending on the level of reliability of the equipment, it is possible to determine the number of equipment to be replaced so that a predetermined number is considered to be in operation at any given time, considered for a certain period of time  $(0, t)$  taken into consideration;
- preventive maintenance operations must be carried out when the intensity or failure rate is increasing over time, the length of time for which the interventions are made is determined by the reliability characteristics of the item or product considered. When the failure intensity is constant, it is obvious that preventive renewal is not necessary.

## **3. Motivating the need to improve the quality of mining equipment**

In the practice of exploiting useful minerals, underground and surface works, there are many reasons that recognize the need to improve the quality of mining equipment and equipment. Of these, the most important are:

- maximizing profits;
- reducing costs due to low reliability, recognizing the particular influence of real costs due to its low value;
- reducing the volume and costs of maintenance and repairs as a result of the reduced frequency of interventions and their reduced duration;
- keeping up with the changes imposed by the global competition;
- the use of higher technical achievements obtained in other areas, such as aerospace or nuclear.

Of all these factors, geological conditions have a particular influence due to their variability underground and surface, which can lead to the impossibility of carrying out the related work and to ensure the optimum conditions of operation of the machinery and equipment.

We must not underestimate the human factor that is of the greatest importance in the design of technological processes, in the production of the equipment and the equipment necessary for the production process, in testing them, in the operation of machinery and equipment, and last but not least in the management of the production activity.

## **4. Determining the quality of mining equipment using the Ishikawa Diagram**

The Ishikawa Diagram, after the name of the Japanese teacher who first built it, is known as the cause-effect diagram. Ishikawa. It is also recognized as the fish skeleton diagram because of its skeletal-like graphic representation.

The Ishikawa diagram is a type of analysis that uses a graphical, causal and suggestive method to optimize the quality of a product, allowing efficient and cost-effective action on the process's technological parameters.

Japanese Ishikawa separates the quality characteristics of a product into real and secondary. The qualitative qualities considered real represent what the customer demands, which is mainly of interest to him and satisfies him during the use of the product. Unlike the actual qualitative characteristics, the secondary ones constitute a minimal system of factors that contribute to determining the process of achieving the main characteristic.

The diagram of the relationship between the actual qualitative characteristic and the secondary characteristics synthesizes a relation between cause and effect. That is why this type of chart is called the cause-effect diagram or the Ishikawa diagram, after the name of the designer.

The real feature becomes the effect and the secondary features are directed towards it. However, it is not about some randomly chosen characteristics, but only those whose role and value compete with the definition of the resultant, represented by the main (real) characteristic.

The cause-effect diagram is therefore a skeletal structure in which the real quality characteristic "effect" is indicated by a backbone, and the secondary characteristics (materials, methods, workers, machines, the environment - known as 5M), which are, in fact, the main causes (important factors) of the problem, are represented in the form of arrows inclined to the spine. Apart from the main factors, there are also some secondary factors, the so-called secondary causes, which are represented by other small arrows directed to the main causes.

## **5. Methods of drawing Ishikawa charts**

In fact, building an Ishikawa diagram, or building it, is not a special issue. It can be said that the drawing of the actual chart is the last operation in a whole series of tests, checks, confrontations and re-evaluations. Once a cause and effect diagram has been drawn up for a given product, it is not the last word; it may be susceptible to improvement, at any time during the course of the product, under the umbrella of uninterrupted technical progress. There are various ways of drawing up Ishikawa diagrams. The proposed methodology for structuring diagrams on the process components involves the following steps:

1. Identify the quality feature that is intended to be improved or kept under control.
2. Write the quality attribute to the right of the format that we want to build the chart and fit into a rectangle.
3. Draw the main line (arrow) from the left to the right; the arrow can be represented by a double line.
4. The main causes (which may be "5M") that influence the quality characteristic are successively written. The main causes also fall into rectangles.

In using an Ishikawa diagram, the following points should be considered:

- Normally, an Ishikawa chart is complicated, with many ramifications. Such a chart is considered good and reflects the deep knowledge of the process;
- if, on the contrary, a diagram of this type has few ramifications, it reflects the superficial knowledge of the process, and so the diagram cannot be considered good;
- after setting a priority in solving the causes, the necessary measures must be laid down to remove these causes. It is very important to monitor the implementation of measures and to check their effectiveness.

## **6. The benefits of using cause-effect charts**

The representation in the cause-effect diagram of all identified causes and factors and interdependence based on the analysis of the company's factors opens the way for the following activities and effects:

1. Analysis of the existing state of the technological process in the analysed sections and workshops. 2. During the creation of the cause-effect diagram, experience and new knowledge are gained by all those who work in this direction. In order to make a correct, complete diagram that clearly represents the phenomenon being researched, it is necessary to gather as many ideas from as many people as possible in the field. In this way, everyone contributes with their own experience, and in the end, by exchanging views on this occasion, new knowledge will be gained.

3. When drawing up a cause and effect diagram, where the topic of discussion is clear, useful conclusions can be drawn on how to act in the future, and many problems that have negative implications in the future are solved. At the same time, I agree with the "beating" directions to improve the business.

4. Through the persistence of permanently seeking the causes of a phenomenon, a deficiency, all the real factors behind the phenomenon are revealed.

5. Analysis of a cause-effect diagram results in the level of technological knowledge of those who make it; the more the diagram can be represented in more detail, more correctly, the conclusion is that working technology is better known in all phases.

## **7. Conclusions**

The first part of the chapter defines the five concepts used in industrial practice, quality, reliability, maintainability, maintenance and availability, the definitions of which result in their structural bonds, all of which equate to the characterization of the functionality of a product.

For defining the concept of quality, it is absolutely necessary to detail the four elements that have been defined. The complexity of the concept of reliability is highlighted, which, in a complete presentation, should include technical, operational, commercial and management approaches.

The factors that contribute to defining the quality of a mining equipment or equipment are highlighted, given the particular circumstances in which they are exploited.

The cause-effect diagram, or the Ishikawa diagram, is a complex way of analyses a product's quality.

The method is based on the detailed determination of the causes that may lead to the appearance of a defect, so that the best possible measures can be taken to remedy it or even prevent it from occurring.

## References

- Baron, T., Isaic-Maniu, A., Tövissi, L., Niculescu, D., Baron, C., Antonescu, V., Roman, I., *Calitate și fiabilitate. Manual practic*. Vol. I-II. Editura Tehnică, București, 1988;
- Băjenescu, I.T. , *Fiabilitatea sistemelor tehnice*. Editura Matrix Rom, București, 2003;
- Cerghit I. *Sisteme de instruire alternative și complementare. Structuri, stiluri și strategii*. Editura Polirom, Iași, 2008;
- Iliș, N., Andraș I., Serafinceanu A., Gruneanțu I., Radu S. - *Noutăți în susținerea abatajelor*. Ed. Universitas, Petroșani, 2002.
- Kovacs, I, Iliș, N., Nan, M.S. - *Regimul de lucru al combinelor miniere*. Ed. Universitas, Petroșani, 2000;
- Nan, M.S., Jula, D. - *Capacitatea sistemelor de transport*. Ed. Universitas, Petroșani, 2000.

# Power Demand of the TK-R 16/8 Turbocompressor Function of Inlet Conditions

Ion Dosa<sup>a\*</sup>, Ovidiu Bogdan Tomuș<sup>a</sup>

<sup>a</sup> Univeristy of Petroșani, Petroșani 332006, Romania

## Abstract

There are indications in literature regarding the possibility of computing the power demand for the turbocompressor depending on variation of inlet air parameters. The formulas found can be applied only for small variations of inlet air parameters, and their precision is poor. This work presents the results obtained by considering a statistical dependency between the variation of power demand and the variation of inlet air parameters for “TK-R 16/8 Iolanda II” turbocompressor.

Keywords: inlet air parameters, power demand, tubocompressor, statistical dependency

## 1. Influence of environmental factors

Parameters of inlet air are function of season and the elevation against the sea level. Air temperature and pressure can be computed using equations found in literature, [Irimie et al. 1994], and they are valid for a gaseous system in equilibrium. Experimental data shows that temperature is dropping at a rate of 1 °C at every 154 m, and the value of polytropic exponent is  $n=1.002$ , [Irimie et al. 1994].

The power demand of the turbocompressor knowing the power demand for conditions denoted with index 1, and the power demand denoted with 2, can be computed for small variation of inlet air flow rate, using equation below, [Bacu et al. 1972, Brădeanu 1977]:

$$\frac{P_{a2}}{P_{a1}} = \frac{V_{a2}}{V_{a1}} \quad (1)$$

where  $P_{a1}$  is the power demand, W, corresponding to  $V_{a1}$  inlet air flow rate,  $m^3 \cdot s^{-1}$ , and  $P_{a2}$  is the power demand corresponding to  $V_{a2}$  inlet air flow rate.

Based on equation above a direct conclusion is that for different inlet conditions which influences the volumetric flow rate, the power demand of the turbocompressor will be different than the one provided by the manufacturer.

A proper assessment of power demand of the turbocompressor as function of inlet air parameters an equation must be found that has to express with good accuracy the effect of the variation of the environmental factors on the compressor power demand.

Variance of atmospheric air parameters can cause large differences in the inlet air density [Dosa 1998], so the use of the relation (1) valid for small variations of the inlet air flow rate [Brădeanu 1972] or density, can induce significant errors in the assessment of power demand.

## 2. Power demand of the turbocompressor

In order to express the most important factors that influence the power demand of the turbocompressor, the power demand is computed using equation below as a function of mass air flow rate at inlet  $m_{asp}$ , inlet stagnation temperature  $T_{asp}^*$ , stagnation pressure at inlet and outlet  $p_{asp}^*$ ,  $p_{ref}^*$  and the polytropic exponent of compression,  $n$  [Brădeanu 1972]:

\* Dosa Ion. Tel.: +40722409040

E-mail address: i\_dosa@hotmail.com.



$$P_{act} = \frac{n}{n-1} \cdot \frac{R \cdot m_{asp} \cdot T_{asp}^* \cdot \left[ \left( \frac{p_{ref}^*}{p_{asp}^*} \right)^{\frac{n-1}{n}} - 1 \right]}{\eta_c \cdot \eta_{tr} \cdot \eta_m \cdot 10^3} \quad [kW] \quad (2)$$

where:  $R$  - gas constant for air,  $J \cdot mol^{-1} \cdot K^{-1}$ ,  $\eta_c$  - the isentropic efficiency of the turbocompressor,  $\eta_{tr}$  - the gear efficiency,  $\eta_m$  - mechanical efficiency.

Applying the above equation to a cooled multistage turbocompressor is difficult due to the fact that it is impossible to accurately measure the air parameters through its evolution at different stages of the turbocompressor.

The polytropic exponent for the single-rotor turbocompressor without cooling can be calculated using equation found in literature [Pimsner 1988], where the unknown is  $l_f$  the work of friction.

Work of friction in different components of the compressor, [Pimsner 1988], is directly proportional to an experimental coefficient and velocity.

In case of turbocompressor the compressed air is being cooled between stages and a result equation (2) cannot be applied for the multistage turbocompressor.

Achieving different degrees of cooling for the same inlet conditions results in a change of the specific volume of the compressed air that is delivered in the next stage, so even in situations where inlet conditions are the same, the power required for compressing the air has different values depending on the degree of cooling achieved in the intermediate coolers.

Computing the work of friction in various components of the turbocompressor was made in the hypothesis of the separate action [Pimsner 1988] of the different types of losses.

In the absence of data on their interaction, the assumption of a strict dependence between pressure, temperature and power values cannot be accepted.

Therefore, it is considered that the link between the analyzed parameters expressed as an equation is uncertain, the dependence of the parameters being rather a statistical dependence.

### 3. Statistical model

In order to elaborate the statistical model, the simplifying assumptions above regarding the hypothesis of the separate action [Pimsner 1988] of different types of losses will be considered. Equation (2) that analytically analyzes the dependence between power demand, pressure and suction temperature suggests the analysis of the separate influence of the two variables.

Since there is a relationship between the inlet pressure and temperature, the variables are not independent, as a result, in order to avoid errors due to the multicollinearity phenomenon, the two variables will be replaced by one, the density of inlet air.

An important consequence of the hypothesis regarding the value of the polytropic exponent is the number of independent variables measured and sorting of measured data.

Consequently, besides the inlet pressure and temperature, respectively the power demand, the following data will be measured: discharge pressure; inlet flow rate, which controls the friction, and consequently the value of the polytropic exponent; inlet and outlet temperature of the cooling water.

For steady water and compressed air flow rate, the difference between inlet temperature of the cooling water and the outlet temperature reflects the cooling conditions.

Equal temperature variances lead to the conclusion that there are similar cooling conditions, so it will be considered that the specific volume of air delivered in different stages remains the same.

Turbocompressor efficiency is considered constant for a given polytropic exponent, as it is the ratio between potential mechanical work and actual compression work.

Equally, drive speed, engine output, gear efficiency is also considered constant.

In conclusion, the data will be sorted according to the inlet flow rate and the increase of cooling water temperature, i.e. the difference between the water temperature at the inlet and outlet of the cooling circuit.

In the studied case, based on the results obtained with equation (1) for small variations of the flow [Brădeanu 1977], it can be stated that choosing linear correlation for the studied variables is the most appropriate.

The quantitative evaluation of the degree of correlation is made using the simple correlation coefficient [Constantinescu et al. 1980]:

$$R_{x,y} = \frac{n \cdot \sum_{i=1}^n x_i \cdot y_i - \left( \sum_{i=1}^n y_i \right) \cdot \left( \sum_{i=1}^n x_i \right)}{\sqrt{\left[ n \cdot \sum_{i=1}^n x_i^2 - \left( \sum_{i=1}^n x_i \right)^2 \right] \cdot \left[ n \cdot \sum_{i=1}^n y_i^2 - \left( \sum_{i=1}^n y_i \right)^2 \right]}} \quad (3)$$

where  $x_i$ ,  $y_i$  are experimentally measured data sets, and  $n$  is the number of these sets.

Due to the random scattering of experimental data it is possible that the value of the simple sampling correlation coefficient is different from 0 even for two independent variables, which is why the significance of the value obtained for  $R_{x,y}$  using equation [Constantinescu et al. 1980] must be verified:

$$H_{calc} = |R_{x,y}| / \sqrt{n-1} \quad (4)$$

The value obtained compares with  $H_\alpha$  the critical value of the simple correlation coefficient.

If calculated value  $H_{calc} > H_\alpha$ , then with the confidence level  $\alpha$  we can say that the variables  $x$  and  $y$  are correlated, otherwise they are independent.

Removing gross errors can be done by calculating for all  $n$  sets of values  $x_i, y_i$  the sampling dispersion  $s_x^2, s_y^2$  and the correlation coefficient.

These values are computed for the  $n-1$  sets remaining after removing the set denoted with  $x^*, y^*$  suspected to be aberrant. The resulting values are denoted by  $s_x^{*2}, s_y^{*2}$  and  $R_{x,y}^*$ , and the value of the equation [Constantinescu et al. 1980] is calculated:

$$R = \frac{(n-1)^2 \cdot (1 - R_{x,y}^{*2}) \cdot s_x^{*2} \cdot s_y^{*2}}{n^2 \cdot s_x^2 \cdot s_y^2 \cdot (1 - R_{x,y}^{*2})} \quad (5)$$

The computed value is compared to the critical value  $R_\alpha$  [4] for different confidence levels  $\alpha$ .

If  $R < R_\alpha$  then the sets of values are considered to be affected by gross errors with confidence level  $\alpha$  and eliminated.

#### 4. Results and conclusions

In order to generate the regression equation, 124 measurements were made [Dosa 1998].

The barometric pressure  $B$ , the ambient temperature  $T_a$ , the discharge pressure of the turbocompressor  $p_{ref}$ , the drive power demand  $P_{act}$  at the motor terminals, the cooling water temperature in the cooling circuit at inlet and outlet  $T_{int}$  and  $T_{ies}$  were measured.

Resulting data were processed using a program based on the algorithm described above, aiming to eliminate the data affected by gross errors, and finding the significance of the calculated simple correlation coefficient [Constantinescu et al. 1988] [Dosa 1998].

In Fig. 1 are presented the power demand values calculated with the equation (1) (denoted by  $x$ ) considering the power  $P_{a1} = 1,95$  MW and the density  $\rho_1 = 1.165$  kg·m<sup>-3</sup> corresponding to the rated inlet conditions.

Large differences between the two sets of values are observed, which justifies the use of regression equations obtained on the basis of experimental data to assess the energy effects of variation of environmental factors.

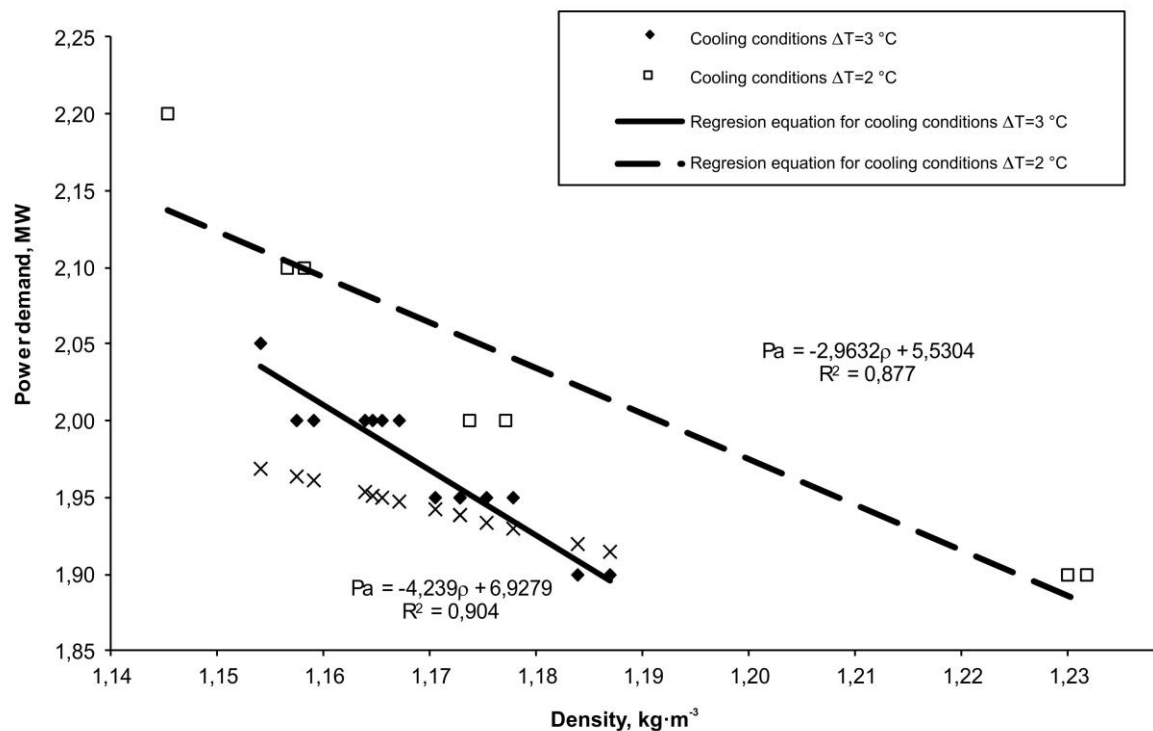


Fig. 1. Variance of power demand at a flow rate of 290.67 m<sup>3</sup>·min<sup>-1</sup>.

## References

- Bacu, A., Bacu, Al. A., *Îndrumător pentru utilizarea aerului comprimat în minerit*, Editura Tehnică, București, 1972.
- Brădeanu, N., *Instalații pneumatice miniere*, Editura Tehnică, București, 1977.
- Constantinescu, I., Golumbovici, D., Militaru, C., *Prelucrarea datelor experimentale cu calculatoare numerice*, Editura Tehnică, București, 1980.
- Dosa, I., *Cercetări privind energetica proceselor termofluidodinamice din instalațiile pneumatice miniere*, Teză de doctorat, Petroșani, 1998.
- Irimie, I., Matei, I., *Gazodinamica rețelelor pneumatice*, Editura Tehnică, București, 1994.
- Pimsner, V., *Mașini cu palete*, Editura Tehnică, București, 1988.
- Radcenco, V., *Criterii de optimizare a proceselor termice ireversibile*, Editura Tehnică, București, 1977.

# Plunger hydraulic machines. Typology, calculation principles and applications in mining

Sorin Vătavu<sup>a\*</sup>

<sup>a</sup> University of Petrosani, 20 University street, 332006, Petrosani, Romania

---

## Abstract

Hydraulic systems are either self-sustaining structures or structures incorporated into different machines, equipment or installations which have different uses, such as: the hydro-mechanical equipment of hydro-electric plants, mining machines and equipment, various machines and tools, construction machines, etc. These systems carry out the transport of the fluid, cool down equipment and, using a pressurised fluid, ensure the lubrication or the transfer of mechanical energy from one conducting element to another. The role of hydraulic energy generators, called pumps, is to supply the systems with the required flow and pressure depending on the destination. As far as the actuating / hydraulic transmission systems are concerned, the pump supplies the operation systems (hydraulic motor and operating device) with the necessary energy for the device to carry out an operation. Mining uses a large variety of operational and constructive types of pumps, piston / pistons machines being integrated in a large and diversified range, determined by the end use of the system, by the domains of the flow, pressure and the operating liquid. The paper deals with the generalities regarding constructive, operational and determination particularities of this type of hydraulic machines largely used in mining.

*Keywords: Hydraulic System; Hhydraulic Machines; Reciprocating Pumps;*

---

## 1. Introduction

Hydraulic systems may be used for various purposes and situations, the most important and widely met are:

- Actuation operating machineries;
- Elastic connection for the shafts;
- Lubrication;
- Fluid transportation.

The general progress reached in different fields of technics have highlighted the remarkable qualities of the hydraulic systems which may be found in wide range of applications, i.e. from agriculture and the low pressure domain to the technical domain with high pressures required to obtain artificial diamonds, over-conductive materials, respectively hydraulic jet stream cutting.

Independent on their destination, the structure of the hydraulic systems comprise sources which generate hydraulic energy, also called pumping assemblies: they are composed of pumps, motors to drive them and eventually monitoring and regulation systems for the hydraulic energy parameters, namely pressure and flow. Moreover, they comprise a hydraulic network composed of a wide range of devices (safety and regulatory elements for pressure and flow, distribution elements, etc.), pipes, tanks and conditioning elements.

Actuation systems comprise execution elements (hydraulic motors) which controllably move the working parts, while the consumers are connected at the end of the transport systems.

Figure 1 brings forward the block diagram of a fluid transport system while Figure 1,b deals with the structure of a hydraulic driving system.

---

\* Corresponding author. Tel.: +4-072-178-3848  
E-mail address: SorinVatavu@upet.ro

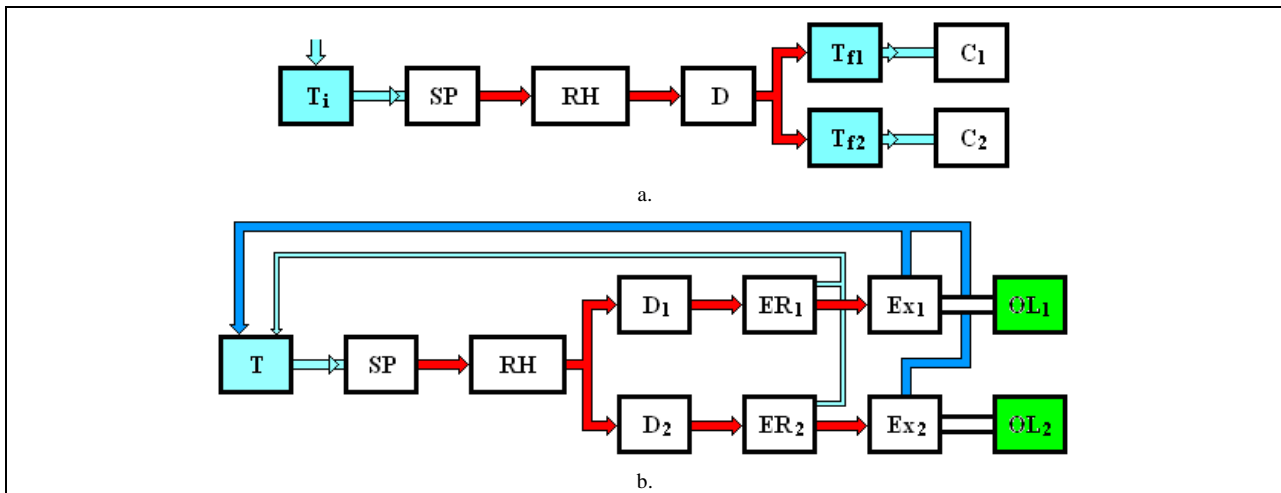


Figure 1. Block diagram: (a) hydraulic system used for transport; (b) actuating hydraulic system

## 2. Basic indicators for hydraulic actuation systems

The use of hydraulic actuation systems is explained by their flexibility which allows the construction of any machine or installation as well as the change and shift from a structure to another according to the changes which might appear.

The experience in the field concerning the use of hydraulic actuation systems to carry out the rotation movement in different domains, proves the necessity to continuously improve the volumetric systems in order to extend the usage range. These systems ensure the possibility to create a series of transmission reports which lead to the creation of momenta or increased speeds at the outlet shaft. In what the rotary hydraulic motors are concerned here are preferences for the ones with axial pistons (70%) and then for those with radial pistons (15%), the rest representing other types of units. The rapid extension of the servo-dynamic electro-hydraulic automatic regulation systems of the cinematic and dynamic parameters of the installations which are not fitted with a mechanic reducer must therefore be mentioned.

Taking into consideration a rectilinear movement it must be mentioned that linear hydraulic motors have been reconsidered, building therefore systems comprised by a single compact pumping assembly also called an electric-hydraulic linear amplifier. Some of the qualities of this equipment are: increased static rigidity in relation to the load, independent on the length of the track; increased response speed; superior reliability; constructive simplicity; lack of mechanic transformer; continuous speed regulation; the easy connection of the measurement and command electronic devices. The improvement of the dynamic qualities of such systems is carried out with the use of command equipment as well as through the improvement of the actuation system.

The development of the technique and the automation systems lead to the extension of the use of pressurised liquid for the operation, command and regulation of the movement of a series of mechanisms which are used for the construction of aircrafts, ships, machineries, agricultural machineries, etc.: namely from the most commonly used hydraulic crank to the huge hydraulic ship lifting installations; from the minuscule servo-valve used in spacecraft technics to the artificial intelligence robot; from the servo-commands of an automobile to those of a tip lorry or giant bucket wheel excavators; from small pressing installations to huge presses used for the synthesis of rough materials and last but not least from simple hydraulic props used to support mine works to complex installations for the actuation of modern mining machines; these are only some of the many applications offered by this large field of hydraulic automated actuations.

## 3. Fundaments for piston hydraulic machines

As it has been previously mentioned, hydraulic machines are used in almost all human activity domains.

Pumps are generator type machines which turn mechanical energy into hydraulic energy, a characteristic specific to all hydraulic systems. Hydraulic motors are a characteristic component of driving hydraulic systems where they move the operating parts of the machines; the turbines of comprise by the hydro-energetic settings are also a part of this category and they drive the electricity generators.

Generally speaking, hydraulic pumps and motors may be found in categories which are established on different criteria. Any classification of hydraulic machineries being either relative or incomplete, the main classification criteria being thus the following: the operating principle, the geometry of its operating parts, its destination, the operating liquid, the actuating mechanism, the operating pressure, etc.

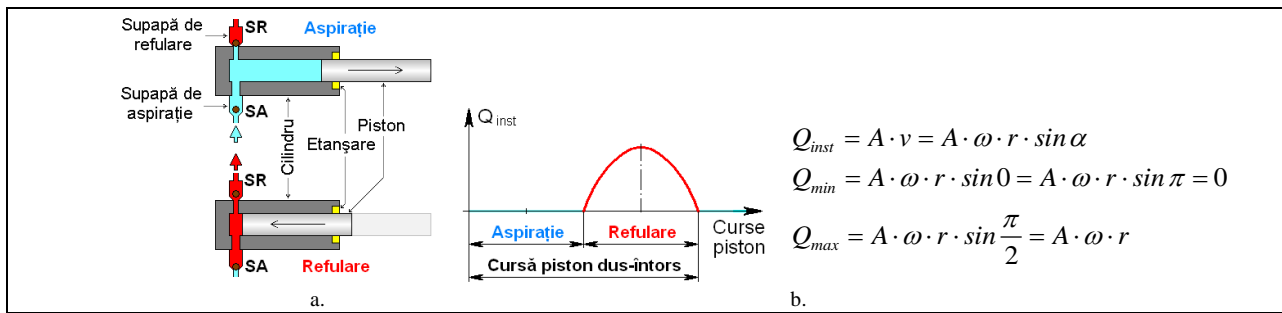


Figure 2. Simple effect piston pump (plunger): a. operating principle; b. the variation of instant flow

Taking into consideration the operating principle, the hydraulic machineries may be classified in:

- Kinetic machineries (centrifuge), also called turbo-machines which, for the conversion of mechanical and hydraulic energies, partially use the pressure energy resulted from the centrifugal forces and the kinetic energy;
- Volumetric machines, for which the energy conversion is generated by the periodic change of the liquid volume which fills in the variable space created by the moving operating parts (pistons, membranes, paddles, cogs, etc.).

The main classification criterion for volumetric machines takes into consideration the shape and the direction of movement of the machine has. According to the direction of movement determined by the closing parts, volumetric machines may be classified as follows: alternative, rotational, rotational-alternative and oscillating.

Piston hydraulic machines have a wide range of usage due to their distinct mechanical and hydraulic performances: from agricultural and building machines to mining machines and hydraulic jets, this type of machines may be encountered as pumps or motors. Nevertheless, the range of piston pumps is much more diverse and ample than the one of hydraulic motors which belong to the same family.

The liquid of the piston pump is pumped through a linear movement into the cylinder of the pump, while, successively and practically in sync, the suction and discharge valves open and close allowing therefore the access of the liquid into the immobilised cylinder of the pump respective the discharge of the liquid from the cylinder.

Piston pumps are classified according to different criteria: depending on the number of active sides of the piston (simple effect, double effect, differential); depending on the build of the piston (disk or plunger); depending on the place of the cylinder and the number of longitudinal axes (simplex, duplex, triplex, multiplex); depending on the pressure during the discharge (low, medium and respectively high pressure); depending on the actuation device (steam, internal combustion, electricity, etc.).

The pumping action of the simple effect pumps only occurs in one direction in which the piston moves (Also called a plunger), only its large surface being active as it is presented in Figure 2.a. When the plunger moves to the right the chamber of the cylinder expands creating thus in the increasing cavity a gap leading to the suction valve SV to be opened and the discharge one DV to be closed: liquid from the suction pipe will replace the free volume created by the movement of the plunger. When the plunger moves to the left it acts upon the liquid increasing its pressure and under the increased pressure the SV closes and the DV opens allowing the liquid to pass through the discharge valve respectively to the consumer. When the operation is repeated the pumping effect is thus obtained.

The pumped flow has an accentuated sinusoidal and pulsatory characteristic related to the active movement (discharge) of the piston: the shape of the instant flow characteristic depending on the movement is presented in Figure 2.b.

In line simple effect piston pumps are largely used, the triplex and pentaplex configuration being the most frequent one, i.e. pumps with 3 and respectively 5 cylinders with plungers placed in line, with lagged operation by  $120^\circ$  for triplex pumps and respectively  $72^\circ$  for five cylinder ones. This is then the result for having compacted in one casing three or five units as it is presented in figure 2, driven by a shaft which has a corresponding number of cranks.

In line plunger pumps are frequently met while operating with increased pressures but also for the hydraulic supply of actuation hydraulic systems found in coal longwall installations. There are also special constructions which contain more units with plungers driven according to a certain logic: for instance, the lubrication systems which are used for the general lubrication of the swivelling mechanisms of bucket wheel excavators.

Piston and block pumps of the swivelling cylinder represents a pumping assembly the operation of which is similar to the operation of plunger pumps. These pumps however lack the suction and discharge valves, and the closing of the operational volumes is carried out through the successive passing of the cylinders into the suction area respectively the discharge area: the pistons have therefore an alternative and rotational movement. These pumps are generally classified as follows:

- Considering the orientation of the plungers compared to the axis of the rotor they may be axial – Figures 3.a and b and radial – Figure 3.c;
- Considering the actuation organ which drives the plungers (cylinder casing – Figures 3.a and c, respectively the driving disk – Figure 3.b).

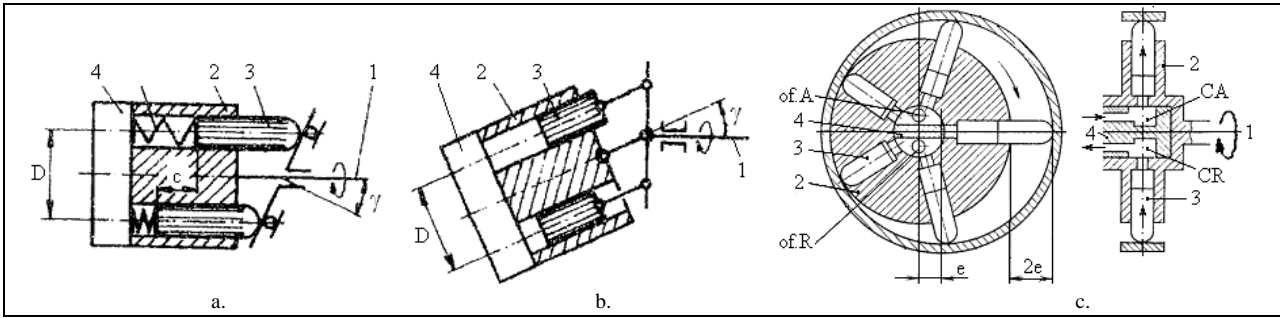


Figure 3. Plunger pumps: a, b. axial; c. radial.

The significance of the indicators presented in Figure 3 is the following: 1 –actuating shaft, 2 –cylinder block, 3 – plunger, 4 –distribution element, SI / DO - suction inlet, discharge outlet, SC / DC –suction / discharge chamber.

Axial and radial piston units are widely used in underground mining as well as surface mining as pumps and hydro-engines comprised by actuation systems for different machines and mining machineries: longwall advance feed cutter and loader units, loading machines, drills, excavators, etc. It must be also mentioned that pumps and hydro-engines are similarly built the difference being the distribution element.

#### 4. Parameters and determination principles for simple action piston (plunger) hydraulic machines

Units having one or more plungers are volumetric machines the parameters of which have a geometric nature (geometric volume / cylinder capacity -  $V_g$ ), hydraulic (effective power of the pump -  $P_{hP}$ , respectively that for driving the motor  $P_{hM}$ , with the flow parameters -  $Q$  and pressure -  $p$ ) and mechanical (pump's driving power -  $P_{aP}$ , effective power of the motor  $P_{mM}$  with revolution parameters -  $n$  and torque -  $M$ ).

Each movement of the plunger shall develop in the cylinder an active volume which has the following value:

$$V = A \cdot c = A \cdot 2r, \quad (1)$$

with one of the measurement units:  $[cm^3/rev]$ ,  $[dm^3/rev]$  or  $[L/rev]$ , respectively  $[m^3/rev]$ , the measurement unit being adequate to the geometric dimensions of the pump. This volume defines the geometric cylinder capacity, the main parameter of this volumetric machine being:

$$V_{gPP} = A \cdot c = \frac{\pi}{4} d^2 \cdot c \cdot z, \quad [volum/rot], \quad (2)$$

where  $d$  is the diameter;  $A$ - area,  $c$ - the sliding of the plunger and  $z$  is the number of plungers,  $r$ - the length of the crank.

The paper will next bring forward only plunger pumps which are used as components by the actuating hydraulic systems. As it has been previously mentioned, their hydraulic parameters are pressure and discharged flow.

The theoretical value of the discharged pressure  $p_{TP}$  is determined by the load  $S_{rezM}$  on the operating organ driven by the motor supplied by the geodesic height for the discharge network  $H_{gP-M}$  (the level difference between the discharge valve of the pump and the supply one of the motor) and the density of the operating liquid  $\rho$ :

$$p_{TP} = p(S_{rezM}) + \rho \cdot g \cdot H_{gP-M}, \quad (3)$$

expressed by one of the measurement units: MPa, bar or  $daN/cm^2$ , respectively at or  $kgf/cm^2$ .

The real value of the pressure is increased by the load losses  $\Sigma h_{rP-M}$  on the connection network between the pump and the motor:

$$p_P = p(S_{rezM}) + \rho \cdot g (H_{gP-M} + \Sigma h_{rP-M}) = p(S_{rezM}) + \rho \cdot g \cdot H_{gP-M} + \Delta p_{P-M} = p_{TP} + \Delta p_{P-M}, \quad (4)$$

where  $\Delta p_{P-M}$  is the pressure loss on this route; for short or quasi-horizontal routes,  $H_{gP-M} = 0$ .

It is thus observed that the discharge pressure of the pump is determined by the load and the hydraulic resistance of the network.

The flow of the pump is in fact the quantity of liquid expressed in volume units or mass units in relation to time units, quantity which the pump takes over from the supply source and transports it towards the consumer. Usually, the volumetric flow is expressed in  $m^3/s$ ,  $m^3/h$  or  $L/min$ .

If the reciprocating pump operates with speed  $n_a$ , then the plunger carries out  $n$  complete slides/time unit and shall discharge an average flow

$$Q_{TPP} = V_{gPP} \cdot n_a = \frac{\pi}{4} d^2 \cdot s \cdot z \cdot n_a, \quad [volume/time]; \quad (5)$$

which evidently emphasises a theoretical flow as it does not take into account the pump's losses considering the measure unit of the capacity and the revolution count, which is expressed in  $m^3/min$  or  $m^3/h$ , respectively  $L/min$ ; most often  $n$  is expressed in  $rev/min$ .



In order to have a real pumped flow then the relation takes into account the volumetric efficiency  $\eta_{VP}$ :

$$Q_{PP} = \eta_{VP} \cdot Q_{TPP} = Q_{TPP} - k_{VP} \cdot p_P, \quad (6)$$

where  $k_{VP}$  is the coefficient of volumetric losses at the pump; the volumetric efficiency depends on the value of the leaks interstices of the pump as well as on the nature of the transported liquid: thus, throughout the same interstice the losses are larger for liquids which have more reduced viscosities. The usual values of  $\eta_v$  which are taken into consideration for the determination of the real flow of a reciprocating pump are comprised between 0.8 and 0.98. the volumetric efficiency does not depend only on the losses through interstices but also on the percentage of filling the free volume generated by the piston during its suction movement: therefore, while using viscous liquid, if the speed of the pump is not correlated to the viscosity, the filling of the space is incompletely carried out with blank spaces into the mass of liquid which obviously deteriorates the volumetric efficiency of the pump.

As it has been previously mentioned (Figure 2.b) the flow of the plunger pumps has a pulsatory characteristic while the characteristic of the instant flow is sinusoidal  $Q_i = f(\sin \varphi_i)$ , a phenomenon which represents one of the main disadvantages of these type of pumps in comparison to the centrifugal pumps the flow of which is continuous: the coefficient of pulsation / the degree of non-uniformity of the flow of piston pumps is the parameter which characterises this pulsation and it is:

$$\delta_Q = \frac{Q_{\max} - Q_{\min}}{Q_{\text{med}}}, \quad (7)$$

where  $Q_{\max}$  is the instant maximum flow,  $Q_{\min}$  – the instant minimum flow and  $Q_{\text{avg}}$  – is the average flow of the pump which may be determined using relation (5):

$$Q_{\text{med}} = V_{gPP} \cdot n_a = A \cdot \omega \cdot r / \pi. \quad (8)$$

The pulsation coefficient of the flow depends thus on the type of reciprocating pump because even if the numerator of relation (7) would remain constant the denominator is changed through the cylinder capacity  $V_{gPP}$ .

Therefore, for the simple effect simplex pump (Figure 2.a) taking into account the diagram in Figure 2.b the following may be observed:  $Q_{\max} = A \cdot \omega \cdot r \cdot \sin \pi / 2 = A \cdot \omega \cdot r$ ,  $Q_{\min} = 0$ , while  $V_{gPP} = A \cdot c$  and it results the coefficient of pulsation  $\delta_Q = \pi$ . There is, though, an analogic procedure for the simple effect duplex pump, the only difference being that for such a type the flow is delivered by two plungers with a delayed operation of  $180^\circ$ : the flows  $Q_{\max}$  and  $Q_{\min}$  have the same values, but  $V_{gPP} = 2A \cdot c$  resulting in the following value  $\delta_Q = \pi / 2$

Considering all what has been mentioned before it results that the non-uniformity degree decreases as the number of cylinder increases: pumps with more plungers with delayed operational phases and equal angles carry out a rather good uniformity of the flow. The pulsation of the flow leads to a pulsation of pressure as well producing a phenomenon of fatigue of the pipes and the sealing elements and deteriorates the dynamic operation mode of the hydraulic motors, reducing their lifespan.

Such a pump is used to supply the hydraulic supports used in coal mines. In Jiu Valley in order to supply the open circuit individual hydraulic roof supports, the main hydraulic pumping assembly ACH 40/200 manufactured by S.C. UPSRUEEM S.A. of Petroșani is used: this have a three cylinder horizontal plunger pump which is able to produce a 40 L/min flow at a maximum pressure of 20 MPa, the pressure regulation domain being between 5 and 16 MPa.

The pumping installation is simple, being foreseen with only one safety valve SV and an accumulator A, without any possibility to regulate the flow, it is installed on the storage tank ST which contains an already prepared oil in water solution. It must be mentioned that the pneumatic-hydraulic accumulator A ensures the attenuation of the pulsations of the flow of the pump as well as the hydraulic shocks in the installation.

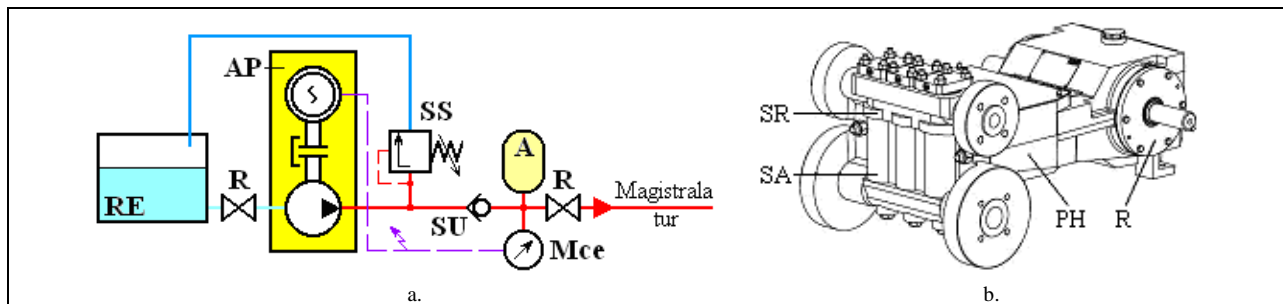


Figure 4. ACH 40/200 pumping assembly: a. hydraulic diagram; b. basic structure of the three plunger pump: PH - pump, R - reducer, SV – suction valves, DV – discharge valves.

The main technical characteristics of the simple action triplex pump are: the cylinder capacity  $\approx 103 \text{ cm}^3/\text{rev}$ ; the diameter / the sliding of the plunger 25 mm / 70 mm; the revolution speed which drives the shaft  $\approx 415 \text{ rev/min}$ ; the nominal power of the electric motor 30(22) kW.

Based on the calculation principles of the plunger pumps and the nominal characteristics mentioned before the geometrical cylinder capacity of the pump used by the ACH 40/200 pumping system, the theoretical discharge flow and the actuating power may be determined:

- The *cylinder capacity* is determined with the help of relation (2):

$$V_{g3P} = \frac{\pi}{4} d^2 \cdot c \cdot z \cong 2,355 d^2 \cdot c = 2,355 (2,5cm)^2 (7cm) = 103,03 cm^3 / rot ,$$

- The *theoretical flow* (i.e. the flow for a null load) is determined using relation (5)

$$Q_{T3P} = V_{g3P} \cdot n_a = 103,03 \frac{cm^3}{rot} 415 \frac{rot}{min} = 42757,45 \frac{cm^3}{min} \cong 42,76 L / min = 0,71 \cdot 10^{-3} m^3 / s ,$$

- Usually, the flow comprised by the characteristics corresponds to the nominal pressure: it allows thus for the determination of the *coefficient of volumetric losses* using relation (6):

$$k_{vp} = \frac{Q_{T3P} - Q_{nP}}{p_{nP}} = \frac{(42,76 - 40) L / min}{200 bar} = 13,8 \cdot 10^{-3} \frac{L / min}{bar} = 0,28 \cdot 10^{-11} m^3 / (Pa \cdot s) ,$$

- The *volumetric efficiency* for a nominal pressure is given by relation (6):

$$\eta_{vp} = 1 - \frac{k_{vp} \cdot p_p}{Q_{TP}} = 1 - 13,8 \cdot 10^{-3} \frac{L / min}{bar} 200 bar / 42,76 L / min = 0,935 ,$$

- The *power necessary to drive* the pump is determined using the following relation:

$$P_{aP} = \frac{P_{hP}}{\eta_{vp}} = \frac{p_{nP} \cdot Q_{nP}}{600 \eta_{vp}} = \frac{200 bar \cdot 40 L / min}{600 \cdot 0,935} = 14,26 kW .$$

As it may be observed, the values determined confirm the parameters specified by the manufacturer: the power of the actuating electromotor may seem too high, but there is the need to have a backup due to the mechanical-hydraulic efficiency of the pump and the efficiency of the connecting transmission.

## 5. Conclusions

Hydraulic plunger machines are widely used in various fields of activity. Due to their qualities and performances they are also recommended to be used in mining both in liquid transport systems as well as in systems which actuate the operating parts of specific machines and equipment.

## Investment portfolio management based on the study of the competitiveness of joint-stock companies

Janusz Wielki<sup>a</sup>, Artem Stopochkin<sup>a\*</sup>, Inessa Sytnik<sup>b</sup>

<sup>a</sup>*Opole University of Technology, Faculty of Economics and Management, Department of E-Business and Electronic Economy, Luboszycka 7 Street, Opole 45-036, Poland*

<sup>b</sup>*Opole University of Technology, Faculty of Economics and Management, Department of Organization and Management of Enterprise, Luboszycka 7 Street, Opole 45-036, Poland*

---

### Abstract

Investing into stock market effectively is possible only when based on scientifically sound methods for analysing investment instruments. The purpose of this study is to develop a method for selecting financial instruments for the formation of an investment portfolio of securities. The proposed method is based on the analysis of the competitiveness of joint-stock companies by identifying the market's capacity, the share price and the company's share in of the stock market turnover. Approbation of the developed method made it possible to identify investment-attractive shares quoted on the Warsaw Stock Exchange. The proposed method has potential to become a scientific basis for effective long-term investment on the stock market.

*Keywords:* investment portfolio; stock market; competitiveness of joint-stock companies; research method; investment portfolio management

---

### 1. Introduction

Respective problems on the Polish market of goods and services make natural persons and legal entities seek new investment opportunities. The securities market may be an attractive place to invest temporarily available funds. The main requirement here is a balanced investment policy based on the use of scientific research methods.

According to the analysed literature, the problem of selecting financial instruments for the effective construction of the investment portfolio plays an increasingly important role in scientific circles.

Scientists, such as the following, among others, are trying to solve this problem:

– T. Węgrzyn in his article “Selection of companies for the portfolio using financial ratios and their relative growth rate – analysis in 2001–2010” [Węgrzyn, 2013]. The main advantage of the proposed method is the use of the relative growth rate; however, the number of analysed indicators, which amount to 26 in four different categories, i.e. profitability, liquidity, management efficiency and debt, makes the application of the method in practice very complicated;

– M. Tymiński and R. Zawiślak in the article “Bi-criterial choice of financial instruments for effective construction and optimization of portfolio on the capital market” [Tymiński and Zawiślak, 2008], which presents the concept of optimisation of the investment portfolio, but do not solve the problem of construction of such a portfolio and the method of selection of companies;

– B. Jabłoński in his article “The role of choice of groups of shares for the investment portfolio on the example of the Warsaw Stock Exchange in 1991–2009” [Jabłoński, 2010]. As the title suggests, the main subject of this study are only the so-called dividend companies. Such an approach is quite interesting, however, it does not make it possible to calculate other factors, such as price changes, market capacity and the company's market share.

It is worth noting that in the above articles, as well as in other papers, all approaches and attempts to solve the problem of selecting companies for the investment portfolio can be divided into methods based on technical analysis [Schwager, 1999; Murphy, 1999] or fundamental analysis [Bulkowski and Thomas, 2012; Ritchie, 1996; Orlova, 2014].

---

\* Corresponding author. Tel.: +48-77-449-88-00, +48-517-535-177; fax: +48-77-449-88-16.  
E-mail address: a.stopochkin@po.opole.pl.

The method proposed in the study attempts to combine these two research methods. The aim of the paper is to develop a scientific method of selecting financial instruments to build an effective portfolio of securities.

The subject of the study are shares of the companies in the banking sector listed on the Warsaw Stock Exchange. The above study is based on the analysis of statistical data from the Warsaw Stock Exchange (Retrieved from <https://www.gpw.pl>) and data available through the MT4 trading platform of the Polish Brokerage House TMS [Retrieved from <https://www.tms.pl>]. The period of the analysis is 1 January 2016–1 October 2017.

## **2. Method of company competitiveness assessment**

The method of company competitiveness assessment proposed in this paper is based on an analysis of the attractiveness of financial investment instruments, namely shares. The proposed method is based on the analysis of the company's share in the securities market (which is both the result of the fundamental analysis – the answer to the question whether the company is a subject of interest of long-term investors – and the result of the technical analysis – since historical data on prices per share speaks of the impossibility of a transaction, which discourages traders from watching it and searching for places to buy or sell it), prices per share (technical analysis – in accordance with the main postulate of the technical analysis theory, the price of an investment instrument is the summation of all factors, including fundamental ones [Bulkowski and Thomas, 2012; Ritchie, 1996]) and market capacity (market demand). It is worth noting that the company's market share depends on the interest of investors and other capital market participants in trading the company's shares. This creates a situation of competition and rivalry in obtaining additional money for the development of the company by means of the securities market. However, this share depends not only on the activity of the company and the results of its own operations, but also on the capacity of the market itself (the amount of capital on the market, the number of large and small players and their activity in a given sector of the securities market).

The first stage (according to the proposed method) consists of finding the largest companies on the stock exchange, which have a significant market value in the sector of interest to the investor. All the data required for the analysis and establishing the investment policy in the market will be divided into basic and extended data. Basic data include: company name and its abbreviated form, date of listing on the stock exchange, number of shares issued. It is proposed to use as extended data the market and book value of the company, P/B ratio (price to book value), P/E ratio (price to earnings) and dividend rate.

According to the proposed method, the best shares for long-term investors are those of companies with a lower P/B ratio. Shares of companies with a P/B ratio below 1.5 may be useful in the investment portfolio. However, for the analysis of a given sector on the securities market, shares of companies with a higher P/B ratio may be taken into account due to their popularity among other investors.

Another indicator that should be used in the analysis of investment instruments on the securities market is the P/E ratio, showing the number of years needed until the profit generated by the company is equal to the invested capital.

Therefore, according to the presented theory, a company with a higher P/E ratio has too high expectations on the part of investors and a correspondingly higher price per share. On the other hand, shares of the company with a lower P/E ratio have more opportunities for potential price increase. The study proposes that companies with a P/E ratio above 20 should be eliminated from the investor's portfolio as such companies may have low operating income levels.

The dividend rate in this method is used as an additional indicator that may influence the investor's decision, however, it does not constitute its main factor.

The second stage of the study is to determine the point at which the market currently is: upper turning point, slowdown, recession, lower turning point, recovery, expansion. The answer to this question gives an opportunity to find the so-called big players on the market and to enter a new trend with them. Each cycle can be divided into smaller parts. Adjust your investment policy and find specific market entry points that are in line with the market trends and technical analysis principles.

Third stage of the study. The results of the third phase of the proposed research method form the basis for a final decision on the shares that are to be included in the investor's portfolio. The proposed method is based on modifications of the rules proposed by J. Bazarnik, T. Grabiński, E. Kąciak, S. Mynarski, A. Sagan on identifying the effects of price change, market capacity and the company's market share when conducting marketing research.

Therefore, the main formula to calculate the overall effect of the change in price per share, the market capacity and the market share of the company is as follows:

$$S_i = Q * U_i * P_i \quad (1)$$

where:  $S_i$  – modified total value of shares turnover selected for the analysis of the company on the stock exchange, in monetary units;  $Q$  – market capacity – modified share turnover of all companies on the stock exchange selected for the analysis, in contractual units;  $U_i$  – share of a given joint-stock company in the total turnover of companies on the stock exchange selected for the analysis, %;  $P_i$  – modified price of the company's shares for the analysed period.

Since each company has its own price and the influence of each company on overall turnover differs, an additional unit of measurement, namely the notional number of shares, is necessary when calculating the company's market share. Under such assumption, the formula for calculating the overall market capacity is as follows:

$$Q = \frac{\sum (Q_i * P_i)}{1000} \quad (2)$$

where:  $Q_i$  – turnover of the company selected for the analysis in the analysed period, number of shares.

The share of the company in the total turnover of the companies selected for the analysis is proposed to be calculated as follows:

$$U_i = \frac{Q_i * P_i}{Q} \quad (3)$$

To calculate the share price for the analysed period ( $P_i$ ), the method proposes to use four prices – the opening price, the lowest price in a given period, the highest price in a given period, and the closing price. Let's assume that these prices have equal weight. Therefore:

$$P_i = \frac{1}{4} P_{otw} + \frac{1}{4} P_{nn} + \frac{1}{4} P_{nw} + \frac{1}{4} P_{zam} \quad (4)$$

where:  $P_{otw}$  – share price of the company, which is the opening price in the analysed period;  $P_{nn}$  – the lowest share price of the company in the analysed period;  $P_{nw}$  – the highest share price of the company in the analysed period;  $P_{zam}$  – share price of the company, which is the closing price in the analysed period.

In order to identify particular spheres of influence of other factors, namely changes in the market capacity, the company's share in trading on the stock exchange and changes in the share prices of individual companies, an effective chain based approach will be applied. This method is based on decomposition using an incremental form with the following formula

$$\Delta S = S_1 - S_0 = Q_i * U_i * P_i - Q_0 * U_0 * P_0. \quad (5)$$

Decomposition is carried out in a strictly defined order using substitutions:

$$\begin{aligned} \Delta S_i = & Q_i * U_i * (P_i - P_0) && \text{Effect of price change.} \\ & + \\ & Q_i * P_0 * (U_i - U_0) && \text{Effect of the change in the shareholding} \\ & + \\ & U_0 * P_0 * (Q_i - Q_0) && \text{Effect of change in demand} \end{aligned} \quad (6)$$

Companies with the highest positive meanings of  $\Delta S_i$  (sum of effect of a given company in the analysed period) may be added to the investor's portfolio. The end result is necessary because the increase of one effect may happen at the expense of the decrease of the other and vice versa.

### 3. Method of company competitiveness assessment

First stage of the study. Assuming that the investor considers investing in shares of companies listed on the Warsaw Stock Exchange, and is interested in the banking sector for the transaction, the main companies in such a case would be those listed in Table 1. The companies in Table 1 are presented according to their market value. The most expensive company is PKOBP; its market value is over PLN 45.625 million, and it has been listed since 2004. The oldest companies selected for the analysis are MBANK and MILLENNIUM (listed since 1992). Their market value is PLN 18,621.18 million and PLN 9,037.72 million, while the P/B ratio is 1.36 and 1.23, respectively.

The youngest companies are ALIOR and GETINNOBLE (listed since the end of 2012). Their market value is PLN 9,113.09 million and PLN 1,343.53 million, while their P/B ratio is 1.43 and 0.27, respectively. In accordance with the proposed theory, there is a strong undervaluation of GETINNOBLE's shares on the market. This suggests the investment attractiveness of such shares. BGZBNPP has to be removed from the investment portfolio because of the P/E ratio, which is higher than standard value (20) and amounts to 40.40.

Second stage of the study. In accordance with the results of the calculations presented in Figure 1, the market was at its lowest turning point at the end of 2016.

The total turnover of the companies on the stock exchange selected for the analysis amounted to PLN 36.75 million and 192.46 thousand shares, with the nearest upper turning point showing the turnover of about PLN 66.13 million and 341.24 thousand shares. The difference between the discussed lower and upper points on the market is PLN 44.87 million (or 49%) and 148.78 thousand shares (or 56%). The analysis shows that the last analysed period (1 October 2017) is also attractive in terms of investment activity oriented towards a longer perspective.

Table 1. Basic and extended data on operations of companies selected for the analysis\*

#	Basic data				Extended data				
	Name	Abbreviation	Listed since	Number of issued shares	Market value, PLN million	Book value, PLN million	P/B ratio	P/E ratio	Dividend rate, %
1	2	3	4	5	6	7	8	9	10
1	PKOBP	PKO	Oct. 2004	1,250,000,000	45,625.00	34,352.00	1.33	16.60	0.00
2	BZWBK	BZW	June 2001	99,333,481	35,909.05	20,615.11	1.74	18.00	1.50
3	PEKAO	PEO	June 1998	262,470,034	33,307.45	21,693.80	1.54	17.50	6.80
4	INGBSK	ING	Jan. 1994	130,100,000	24,842.60	11,154.10	2.23	19.90	0.00
5	MBANK	MBK	Oct. 1992	42,311,255	18,621.18	13,654.95	1.36	18.40	0.00
6	ALIOR	ALR	Dec. 2012	129,263,624	9,113.09	6,388.14	1.43	14.30	0.00
7	HANDLOWY	BHW	June 1997	130,659,600	9,065.16	6,482.83	1.40	19.00	6.50
8	MILLENNIUM	MIL	Aug. 1992	1,213,116,777	9,037.72	7,339.77	1.23	15.50	0.00
9	BGZBNPP	BGZ	May 2011	84,238,318	5,370.19	6,381.02	0.84	40.40	0.00
10	GETINNOBLE	GNB	Jan. 2012	901,696,125	1,343.53	5,029.19	0.27	0.00	0.00

\*Data current as at 19 October 2017

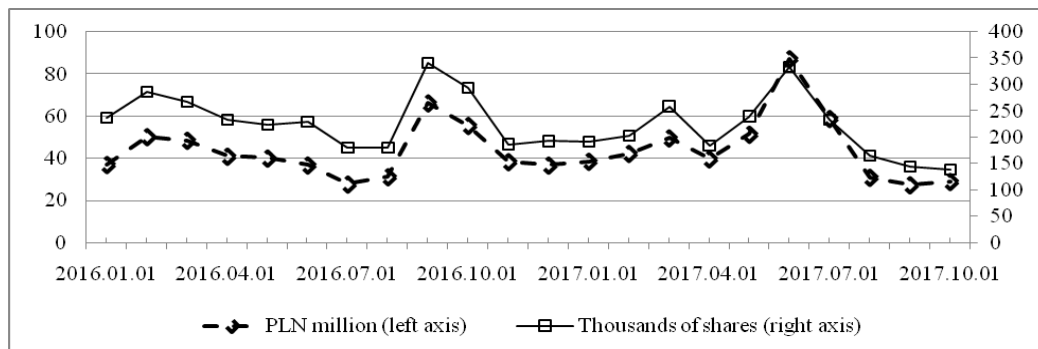
Source: own study based on official data of the Warsaw Stock Exchange [Retrieved from <https://www.gpw.pl>]Source: own study based on official data of the Warsaw Stock Exchange [Retrieved from <https://www.gpw.pl>] and data available through the MT4 trading platform of the Polish Brokerage House TMS [Retrieved from <https://www.tms.pl>]

Fig. 1. Turnover of shares of companies on the Warsaw Stock Exchange selected for the analysis

At this stage of the analysis, the study periods were established, namely: T0 – starting point (1 January 2016); T1 – first study period (1 January – 1 December 2016); T2 – second study period (1 January 2016 – 1 October 2017).

Third stage of the study. The calculations of market shares of respective companies selected for the analysis are presented in Table 2.

Table 2. The share of companies in the turnover on the stock exchange in accordance with the proposed method of company competitiveness assessment\*

Index	Name of the bank	Study period			Accrual ( $\Delta$ )	
		T0	T1	T2	T1 - T0	T2 - T0
Share ( $U_i$ ), %	PKOBP	2.34	1.80	2.26	-0.54	-0.09
	BZWBK	33.50	38.07	28.08	4.57	-5.42
	PEKAO	15.98	9.37	4.73	-6.61	-11.25
	INGBSK	3.48	2.77	7.17	-0.72	3.69
	MBANK	36.19	41.76	48.49	5.57	12.30
	ALIOR	4.25	2.96	7.20	-1.29	2.95
	HANDLOWY	4.17	2.77	1.96	-1.40	-2.21
	MILLENNIUM	0.09	0.04	0.11	-0.05	0.02
	GETINNOBLE	0.0008	0.0019	0.0063	0.00	0.01

Source: own study based on official data of the Warsaw Stock Exchange [Retrieved from <https://www.gpw.pl>] and data available through the MT4 trading platform of the Polish Brokerage House TMS [Retrieved from <https://www.tms.pl>]

According to the results, the largest market share is held by MBANK – 48.49% of transactions in the T2 period, which at 12.30 p.p. is more than at the starting point. PEKAO (share decreased by 11.25 p.p.) and BZWBK (share decreased by 5.42 p.p.) lost the most shares in the analysed period. INGBSK and ALIOR gained increasing investor confidence. HANDLOWY occupies the third place, which corresponds to the change of market share by 2.21 p.p. Therefore, from the point of view of a potential investor in the T1 period, it is worth noting MBANK and BZWBK companies. Investing in PEKAO would suggest significant losses.

The company with the highest price per share, according to calculations, is MBANK with price per one share of PLN 437.13 (Tables 2 and 3). For the analysed period T2 (1 January 2016–1 October 2017), the share price of this company increased by PLN 137.69. At this stage of the analysis, the increase of  $\Delta(T1-T0)$  should be noted. From the investor's point of view, the following companies are worth noting: BZWBK, INGBSK and MBANK.

Table 4 presents the results of calculation of the turnover of companies on the stock exchange in accordance with the proposed method of company competitiveness assessment. According to the data, in the T1 period in relation to the starting point T0 the highest turnover was lost by PEKAO (78.18% of turnover). The turnover of HANDLOWY and BZWBK decreased by 63.95% and 10.24%, respectively.

Table 3. The price of one share of companies on the stock exchange in accordance with the proposed method of company competitiveness assessment

Index	Name of the bank	Study period			Accrual ( $\Delta p$ )		
		T0	T1	T2	T1 - T0	T2 - T0	T2 to T0, %
Price per share (P), PLN	PKOBP	24.97	26.80	36.27	1.83	11.30	45.27
	BZWBK	259.16	304.99	354.29	45.83	95.13	36.70
	PEKAO	135.56	121.59	127.60	-13.97	-7.96	-5.87
	INGBSK	111.36	155.25	195.68	43.90	84.32	75.72
	MBANK	299.44	331.93	437.13	32.49	137.69	45.98
	ALIOR	61.50	49.31	69.99	-12.19	8.50	13.81
	HANDLOWY	71.17	71.95	69.77	0.77	-1.41	-1.98
	MILLENNIUM	5.21	5.26	7.30	0.05	2.09	40.09
	GETINNOBLE	0.5275	1.2425	1.4825	0.72	0.96	181.04

Source: own study based on official data of the Warsaw Stock Exchange [Retrieved from <https://www.gpw.pl>] and data available through the MT4 trading platform of the Polish Brokerage House TMS [Retrieved from <https://www.tms.pl>]

Table 4. The turnover of companies on the stock exchange in accordance with the proposed method of company competitiveness assessment

Index	Name of the bank	Study period			Accrual ( $\Delta p$ )		
		T0	T1	T2	T1 - T0	T2 - T0	T2 to T0, %
Turnover (Si)	PKOBP	21.65	17.76	23.72	-3.88	2.07	9.56
	BZWBK	3,213.45	4,267.17	2,884.32	1,053.72	-329.14	-10.24
	PEKAO	801.64	418.64	174.95	-383.00	-626.69	-78.18
	INGBSK	143.60	157.89	406.86	14.28	263.25	183.32
	MBANK	4,011.16	5,093.90	6,145.46	1,082.75	2,134.30	53.21
	ALIOR	96.74	53.58	146.18	-43.16	49.44	51.10
	HANDLOWY	109.89	73.17	39.61	-36.72	-70.28	-63.95
	MILLENNIUM	0.17	0.08	0.24	-0.09	0.07	37.31
	GETINNOBLE	0.0002	0.0009	0.0027	0.00	0.00	1,673.92

Source: own study based on official data of the Warsaw Stock Exchange [Retrieved from <https://www.gpw.pl>] and data available through the MT4 trading platform of the Polish Brokerage House TMS [Retrieved from <https://www.tms.pl>]

The analysis of turnover of the companies selected for the analysis confirms the results of the previous stages and indicates the advisability of investing capital in the shares of BZWBK and MBANK in the period T1. However, the final decision regarding the investment portfolio can be made after the calculation of individual effects of changes in demand, prices per share and market shares of the company for companies. The results of these calculations are presented in Table 5.

Table 5. Respective effects of changes in competitiveness of companies on the market

Name of the bank	Demand effect		Share effect		Price effect	
	T1	T2	T1	T2	T1	T2
PKOBP	-154.88	-4691.10	-4944.78	-63067.73	1214.66	739124.84
BZWBK	-22989.14	-696312.44	435557.94	-40725284.68	641151.39	77442903.05
PEKAO	-5734.95	-173704.47	-329155.06	-44207301.54	-48108.92	-1091365.35
INGBSK	-1027.35	-31117.01	-29330.74	11904740.49	44640.25	17532173.18
MBANK	-28695.94	-869164.30	612873.47	106774473.31	498571.12	193572298.70
ALIOR	-692.10	-20962.73	-29218.72	5265854.99	-13249.97	1774186.02
HANDLOWY	-786.17	-23812.03	-36724.47	-4566648.43	788.16	-79920.29
MILLENNIUM	-1.25	-37.88	-93.47	3442.03	0.77	6869.49
GETINNOBLE	-0.001	-0.033	0.21	84.46	0.49	174.57

Source: own study based on official data of the Warsaw Stock Exchange [Retrieved from <https://www.gpw.pl>] and data available through the MT4 trading platform of the Polish Brokerage House TMS [Retrieved from <https://www.tms.pl>]

According to the results of the study, almost all companies lost from the change in market capacity in the analysed periods T1 and T2. This indicates a decrease in the number of investors and capital on the Polish securities market in the banking sector.

Almost all companies incurred losses on the share effect in the specified T1 study period. Only MBANK, BZWBK and GETINNOBLE were able to achieve a positive value of the share effect in the T1 period. According to calculations, the negative price effect in the T1 period can be observed in the case of two companies – PEKAO and ALIOR. It shows that, assuming that market shares can be maintained and that market capacity remains unchanged, these companies would lose the confidence of investors in any case and there is currently insufficient interest in them.

Let's try to determine the total competitiveness effect of companies on the market. Calculations show that only four companies in the T1 period can be satisfied, namely MBANK, BZWBK, INGBSK and GETINNOBLE. Despite the fact that the overall turnover on the stock exchange decreased, they managed to achieve a positive total effect of the change in turnover, thanks to maintaining the interest of investors in the operations of companies and increasing their shares, which resulted in an increase in the prices of their shares.



If the conducted study on historical data of changes of share price of companies selected for investment in the T1 period indicates that the effectiveness of the investment portfolio meets the investor's requirements, then in the period T2 companies MBANK, BZWBK, INGBSK, ALIOR, PKOBP, MILLENIUM, GETINNOBLE will be worthy of interest in terms of investment.

Due to the P/B ratio, adding BZWBK (1.74) and INGBSK (2.23) to the portfolio of shares may increase the risk for the investor, but it may also increase the profitability of the portfolio (the price may continue to rise as the profitability of operating activities of these companies increases). The companies with the highest risk in the T2 period, according to the results of the analysis, are HANDLOWY and PEKAO (in the T2 period, the negative meaning of the total effect is greater than in the T1 period).

#### 4. Summary

Based on the obtained research results, as of 1 October 2017, the shares of such companies as the following have been attractive for purchase in order to invest on the stock exchange: MBANK, BZWBK, INGBSK, ALIOR, PKOBP, MILLENIUM, GETINNOBLE.

The method of analysis of companies competitiveness presented in the study may become an effective tool for long-term investment on the securities market. This method is based on three basic indicators: total turnover on the stock exchange of selected companies, the company's market share and the price per share. Practical application of the described method may increase the attractiveness of investing in securities markets.

#### References

- The Warsaw Stock Exchange Company. Retrieved from <https://www.gpw.pl>
- TMS Brokers Europe Ltd. Retrieved from <https://www.tms.pl>
- Węgrzyn, T. *Dobór spółek do portfela z wykorzystaniem wskaźników finansowych i ich względnego tempa przyrostu. analiza w latach 2001-2010*. Studia Ekonomiczne. Wydawnictwo U E w Katowicach, 174, 63-74, (2013)
- Tyminski, M., Zawislak, R. *Dwukryterialna koncepcja wyboru instrumentów finansowych dla efektywnej konstrukcji portfela i jego optymalizacja na rynku kapitałowym* – Zeszyty Naukowe Uniwersytetu Szczecińskiego. Finanse. Rynki finansowe. Ubezpieczenia, 13, P. 415-426, (2008)
- Jablonski, B. *Znaczenie wyboru grup akcji do portfela inwestycyjnego na przykładzie Warszawskiej Giełdy Papierów Wartościowych w latach 1991-2009*. Prace Naukowe. Akademia Ekonomiczna w Katowicach. Tom: Dokonania współczesnej myśli ekonomicznej – znaczenie kategorii wyboru w teoriach ekonomicznych i praktyce gospodarczej, P. 399-411, (2010)
- Jack D. Schwager, *Getting Started in Technical Analysis*. – New York: John Wiley & Sons Inc, 352 p., (1999)
- John J. Murphy. *Technical Analysis of the Financial Markets: A Comprehensive Guide to Trading Methods and Applications*. - New York: Institute of Finance, 576 p., (1999)
- Bulkowski, Thomas, N. *Fundamental Analysis and Position Trading: Evolution of a Trader*. – Wiley, 320 p., (2012)
- Ritchie, John, C. *Fundamental Analysis: A Back-To-The Basics Investment Guide to Selecting Quality Stocks*. – Irwin Professional Pub; Revised, Subsequent edition, 394 p., (1996)
- Orlova N.S. *Issues of Non-bank Financial Institutions Investment Activity in Ukraine. The Journal of Financial Management and Accounting*. – Warsaw. - SGGW: 2014. – №3. – P. 6-9
- Bazarnik, J., Grabiński, T., Kaciak, E., Mynarski, S., Sagan A. *Badania Marketingowe. Metody i oprogramowanie komputerowe*. – Canadian consortium of management schools. Akademia ekonomiczna w Krakowie. - Warszawa – Kraków, P. 119-121, (1992)

# The Development of Community Based Tourism: from Attractiveness to Loyalty

Nur Feriyanto<sup>a</sup>, Sebastian Kot<sup>b\*</sup>, Dyah Sugandini<sup>c</sup>, Muafi<sup>d</sup>

<sup>a</sup>Economic Department, Economic Faculty, Universitas Islam Indonesia

<sup>b</sup>The Management Faculty, Czestochowa University of Technology and Faculty of Economic Sciences and IT, North-West University

<sup>c</sup>Management Department, Economic Faculty and Business Faculty, Universitas Pembangunan Nasional “Veteran” Yogyakarta

<sup>d</sup>Management Department, Economic Faculty, Universitas Islam Indonesia

---

## Abstract

This research aims to test the loyalty of tourists who visit tourism village as one of the community based tourism. The loyalty model that is proposed explores the relationship between attractiveness, trust, service quality, positive attitude, intention to visit, and intention to recommend. This research uses the respondent survey of domestic and foreign tourists who visit community based tourism tourist village in the Province of Daerah Istimewa Yogyakarta (DIY), Indonesia. The sampling technique is using purposive sampling with the respondent criteria of tourists who are motivated to visit because of special intention. The number of respondent is 400 people. The data analysis technique is using Structural Equation Modeling (SEM). This research result explains that the research model is accepted, this means that there is a relationship between attractiveness, trust, service quality, positive attitude, intention to visit and intention to recommend. This research result gives a direction for the manager of tourism village about the increased tourist loyalty through infrastructure improvement either in tourism location or home stay provided by the community, ease of access, security, hospitality, and professional tour guide. This research has originality such as the setting of tourism village based community and analyze tourists loyalty with the antecedent of trust and attractiveness which mediated by service quality and positive attitude that is different with tourist loyalty model that have been researched before.

**Keywords:** *trust; attractiveness; quality; attitude; loyalty.*

---

## 1. Introduction

Community based tourism (CBT) in the context of sustainability tourism development has a very important role. CBT can empower the community through a sustainable tourism management and give priority to the community as central position in the management of tourism are. CBT is the management of community-based tourism that provide many opportunities to the empowerment of local community, especially in developing country (Sugandini et al., 2017b; Diharto et al., 2018; Wróblewski, et al., 2017, Kurowska-Pysz, 2015). The community involvement in the management of these tourism areas will also give an important role for the community in maintaining and developing tourism village to be sustainable and building a strong regional economic activity for the sustainability of household economy and the welfare of the community itself (Feriyanto, 2016a; Feriyanto, 2016b).

The research about CBT is important to be done because: (1) the measurement of CBT impact is still difficult to observe, because it is indirect and intangible. The economic impacts are easier to be analyzed, but the social and environmental impacts are very difficult to be measured; (2) local issues has a direct impact on tourism experience, a bad experience with local community can bring a hostility toward tourists, so understand the positive attitude of tourists toward a CBT can show an alignment that occurs between local community and social climate which will have an impact on tourism benefits and there will be no victim of the existence of CBT (Wahab and Pigram, 1997); (3) trust is usually studied only for electronic-tourism context (Nguyen et al., 2011), e-loyalty, online tourism and information technology related to tourism (Diharto, et al., 2018). This research studies about trust in relation to trust toward

---

\* Corresponding author.

E-mail address: sebacat@zim.pcz.czest.pl

community-based tourism destination sites. Trust toward local community, natural environment, infrastructure, facilities, and special events or festival become an important factor to be considered in this research.

This research tests the impact of CBT from the success of CBT. The success of CBT can be seen from the increasing loyalty of tourists towards community-based tourism destination. The loyalty of this research is seen from the intention to visit community-based tourism and intention to recommend the tourism to other potential tourists/travelers. Loyalty becomes important to be analyzed because if the loyalty program is managed properly, it is very possible to manage and control the buying behavior of the tourists (Sugandini et al, 2018d; Štefko, et al., 2017). Loyalty also become an important contributor in gaining profitability (Darnell and Johnson, 2001; Hsu et al., 2008, Simarmata, et al., 2017).

This research was conducted to test the model of tourist loyalty in CBT in the Province of DIY. CBT that is analyzed is a special interest type of tourism, such as home stay, nature tourism, and live in tourism village. Some tourism village in DIY offer educational, cultural, and natural tourism for their visitor. These tourism villages also offer traditional game facilities such as *enggrang*, *engklek*, *dakon*, *gobaksodor*, and others, which can be played in that location. Tourism village in DIY also has a very beautiful scenery, fresh air, and a clear and well-maintained river. There are also home stay as a place to stay for the tourists that equipped with a restaurant provided by the community. Tourism villages in DIY are fully managed by the community, empowered by the community, and it is include in community-based tourism (CBT). This research is conducted based on the approach of social exchange theory, because in CBT there is a high involvement between community and tourists, so the high involvement will create social exchange between the two. Social exchange theory can show a framework of reference where the theories are built based on several assumption about human and relationship nature. This theory can be used to explain the use relationship between community and tourists in community-based tourism destination, because there is a very strong interaction between tourists, manager, and community (Sugandini et al., 2018c; Diharto, et al., 2018).

## 2. Literature review

### 2.1. Social Exchange Theory

Social exchange theory is a general sociological theory (Ward and Berno, 2011), which can be applied on the exchange of tourism resource, travel experience, and social interaction between tourism stakeholders. This theory sees interpersonal relations as a commercial transaction. Social exchange theory is rooted in economic theory, social psychology, and sociology. Social exchange theory is that every individual are voluntarily enters and stays in social relationship as long as the relationship is satisfying, in terms of rewards and costs.

### 2.2. Attractiveness, service quality and positive attitude

Ajzen (1991) defined attitude toward behavior as “how far a person has a favorable or unfavorable situation of a product and service”. Several factors affect tourists’ attitude toward tourism destination can be classified into two major determinants. According to Middleton and Fyall (2009), several factors that affect tourists’ attitude is the attraction of tourism destination such as nature condition, culture or entertainment events, the availability of major and supporting facilities in the tourism destination, accessibility, image, price level, and the quality of destination and promotion from tourism organization to introduce a tourism destination (Sugandini et al, 2018a; Muafi, 2017; Roostika and Muafi, 2014).

Besides affecting attitudes, attractiveness also has a positive influence toward destination quality (Al-Ababneh, 2013; Roostika and Muafi, 2014). Perceived service quality of a destination includes a good souvenir, a restaurant, and a comfortable lodging. A person who perceived attractiveness of a good tourism destination will affect the perceived service quality of a destination, and it will subsequently affect the positive attitude (Sugandini and Djawoto, 2018).

*H1: Attractiveness has a significant positive impact towards perceived service quality*

*H2: Attractiveness has a significant positive impact toward positive attitude*

*H3: Perceived Service quality has a significant positive impact toward positive attitude*

### 2.3. Trust, service quality, and positive attitude

Singh and Sirdeshmuskh (2000; Garbarino and Johnson, 1999), stated that if the customer does not trust the company, the customer will not place his first purchase. Trust is an important determinant factor of attitude formation and loyalty (Chinomona, 2016). According to the commitment-trust theory (Morgan and Hunt, 1994), trust is the main variable in the development of a lasting desire to maintain a long-term relationship with brand (Nguyen et al., 2011). When consumers have a level of trust, they will be more likely to have a positive attitude with the service (Kim, et. al., 2008; Muafi, 2017). Hsiao, et al. (2010) shows that trust is positively affect attitude and subsequently, intention to purchase.

*H4: Trust has a significant positive impact toward perceived service quality*

## 2.4. Positive attitude and loyalty

The loyalty toward service provider is considered a major consequences from positive attitude (Susilowati and Sugandini, 2018; Yu and Dean, 2001). Tourists' loyalty to a destination is showed by their intentions to revisit the destination and their willingness to recommend it (Oppermann, 2000). Recommendations by previous visits can be used as a credible source of information for potential tourists. Recommendation to others through word-of-mouth is a type of information that is needed by people who will visit a destination. The proposed hypothesis is as follows:

*H5: Positive attitude has a significant positive impact toward intention to visit*

*H6: Positive attitude has a significant positive impact toward intention to recommend.*

## 3. Research method

This research is a survey research. Respondents that is used in this research is tourists who is motivate to visit natural tourism and special interest destination (tourism village and live in it). These respondents are considered the most appropriate respondents in predicting tourist loyalty of CBT. The population of this research is tourists who visit community-based tourism destination in the Province of DIY, such as tourism village of Kembangarum, Kasongan, Bleberan, Kampong cyber, and Nglingo. The number of respondents are 500 people. The response rate is about 80%, so there is 400 people. The data analysis technique is using Structural Equation Modeling. The direct influence is observed from standardized regression weights with comparable significance test of CR (Critical Ratio) value that equals to t test values (Sugandini et al, 2018a; Muafi, 2017). The significance assessment is based on the probability (p) value and the limit of significance that is used is the p value  $\leq 0,05$ . The test toward the model is developed with various criteria of Goodness of Fit, such as Chi-square, probability, RMSEA, GFI, and TLI (Hair et al., 1998). This research is using the data collected from 400 CBT tourists in DIY. The result of confirmatory factor analysis explained that the six construct which is: attractiveness, trust, service quality, positive attitude, intention to visit, and intention to recommend are consist of 22 question items which are stated to have a good validity because they have standardized factor loadings  $\geq 0.3$  and reliable, which shows from the value of *construct reliability* over 0,7 and the recommended *variance extracted* is  $\geq 0,50$  (Hair et al., 1998).

## 4. Research result

The majority of respondents are man, which is about 65%. Special interest tourism are more favored by men because there are tracking facilities and others that are also very popular, such as river, waterfalls, and mountain climbing. The age of the respondents are mostly  $\leq 20$  years old, which is about 51%, tourists with educational background of junior high school and senior high school is about 56%, tourists with the background job of student and college student is about (43%), because the destination in this tourism village are mostly visited by student and college student as the place to live in and outbound. The CBT is special interest, which is tourism village and live in (stays in the village). The test result of consumer loyalty SEM model using AMOS can be seen on Figure 1. The result of model evaluation explain that the criteria of goodness of Fit which is; cmin/DF, probability, RMSEA, GFI, TLI and CFI are fulfilled. It can be explained that the model can be accepted. In order to test the causal relationship between attractiveness, trust, service quality, positive attitude, intention to visit, and intention to recommend, it is presented a path coefficient that shows the causal relationship between those variables. The hypothesis test is conducted by comparing the probability (p) value. It is consider significant if the p value is  $\leq 0.05$ . By using the criteria, it can be seen that all paths are significant, so all hypothesis are accepted.

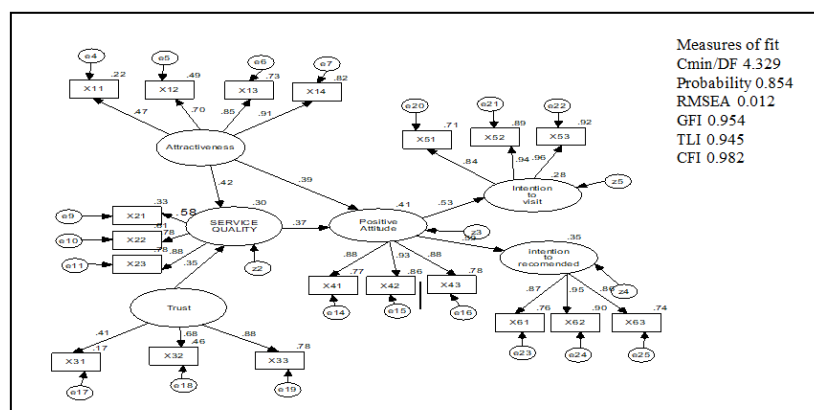


Fig 1: The Test Result of Model

## 5. Discussion

This research result explained that the structural loyalty model in the CBT is fit, which means that the loyalty model can be explained by attractiveness, trust, service quality, positive attitude, intention to visit, and intention to recommend. The influence of attractiveness toward loyalty (intention to visit and intention to recommend) in this research supported the research findings from Middleton and Fyall (2009); Horner and Swarbrooke (2007). Tourists who perceive that the tourism village has a high attractiveness will affect perceived service quality, positive attitude, and loyalty (Sugandini, 2003; Roostika and Muafi, 2014). Tourists who visit the tourism village will feel that the natural scenery in the tourism village in DIY is very beautiful, fresh, and natural. This tourism village also has easy access and there is a homestay as a place for the tourists to stay. This tourism village has a professional tour guide who can speak foreign language quite well. The influence of trust toward perceived service quality is also supported, which means that tourists who visit tourism village in DIY can feel confident with the honesty of community in the tourism village and believe that others will not utilize their presence in the tourism village. The tourists also feel that the infrastructure in the tourism village has a good quality, the village is also safe, they received a quite clear information, and the tourism village has a friendly and on-time service. This research result is also supports the research findings by Singh and Sirdeshmuskh (2000); Garbarino and Johnson (1999); Nguyen et al., (2011); Chinomona (2016); Slusarczyk et al., (2016).

The influence of positive attitude toward loyalty is also supported. This means that the tourists have positive attitude toward the tourism village in DIY, which is showed by the tourists' pleasure of their visit, their happiness to interact with a different life style, and the existence of a sense of togetherness. This positive attitude is also able to increase the loyalty of tourists, which is showed by their desire to visit this tourism village in the future, making this tourism village as the main tourism destination, and their desire to recommend this tourism village to others. The result of this study supports the research result from Oliver (1981, 1997); Susilowati and Sugandini (2018). Their findings stated that positive attitude has a positive contribution toward destination loyalty, which is showed by their intention to revisit the destination and their willingness to recommend.

This research contributes in addressing three gaps in the previous tourism literature by exploring the influence of trust, attractiveness, perceived service quality, and positive attitude in the destination loyalty with CBT setting. *First*, this research analyzes the loyalty of the tourists using attractiveness and trust as the antecedent in the community-based tourism that is different with other types of tourism. During this time, trust variables are mostly used in the setting of e-tourism (Koufaris and Hampton-Sosa, 2004; Salo and Karjaluoto, 2007; Yung Yeh and Li, 2009), trust is also rarely used in CBT settings (Sugandini et al., 2018b). This research contributes in the influence of trust toward tourists' loyalty that mediated by service quality and positive attitude on the CBT setting, so that it can strengthen the previous literature about the influence of trust. *Second*, this research also analyzes the influence of attractiveness toward loyalty by mediating perceived service quality and the positive attitude of the tourists. Previous studies have shown that attractiveness can directly affect loyalty (Wu et al., 2015; Wu, 2016). This research succeed in showing that attractiveness can affect loyalty through the mediation of service quality and positive attitude. Attractiveness can also affect the positive attitude of the tourists, either through mediation or through direct variables. This research also shows the direct influence of positive attitude toward loyalty.

*Third*, this research extends loyalty model by analyzing the variable of attractiveness, trust, service quality, and positive attitude. This research does not use satisfaction to predict loyalty as it has been widely used by previous researchers (Sugandini et al, 2017a, Sugandini et al., 2018b; Jianqiong et al., 2018). This research uses positive attitude to predict loyalty. The research settings are on the type of special interest tourism, such as home stay and live in that exist in DIY, Indonesia. This research result can increase external validity of the findings of the previous research about tourists' loyalty that have existed before.

The result of this research is also can show that tourists' loyalty can be increased through the improvements in infrastructure both in the tourism attractions and on home stay provided by the community. Ease of access, security, hospitality, and professional tour guide are also able to grow a positive attitude of tourists in the tourism village. Thus, in the end this positive attitude will affect tourists' loyalty. The development of tourism objects and attraction will be able to bring more tourists from time to time to provide a great economic contribution for the region from taxes and levies that are needed as a source of funds for regional expenditures for economic development of district/city in DIY (Feriyanto, 2016a; Feriyanto, 2016b; Haryono et al., 2017).

## 6. Limitation and Future Research Directions

This research only explores the success model of CBT from the side of the consumers, which is measured by tourists' loyalty who visit the tourism village. The measurement of CBT impact should also explore the impact of CBT for the community. For future research, researcher should do research by taking the dyad setting, which combines the perception between tourists and CBT managers. This can be done using the research method of multi trait multi method. In this way, researchers will get a clear picture about the success of CBT from all aspects.

## References

- Ajzen, I., "The Theory of Planned Behavior", *Organizational Behavior and Human Decision Processes*, Vol. 50(2), pp: 179-211, (1991).
- Al-Ababneh, M., "Service Quality and its Impact on Tourist Satisfaction", *Interdisciplinary Journal of Contemporary Research in Business*. Vol. 4 (12), pp: 164-177, (2013).
- Chinomona, R., "Brand Communication, Brand Image and Brand Trust as Antecedents of Brand Loyalty in Gauteng Province of South Africa", *African Journal of Economic and Management Studies*. Vol. 7 Issue: 1, Pp: 124-139, (2016).
- Darnell, A.C., and Johnson, P.S., "Repeat Visits to Attractions: A Preliminary Economic Analysis. Tourism Management", Vol. 22(2), pp: 119-126, (2001).
- Diharto, A.K., Ismail, Y., Iriantini, D.B., Murtadlo, M.B., and Muafi., "The Role of Community Based Tourism Based on Local Wisdom Using Online Media", *International Journal of Civil Engineering and Technology*, Volume 9, Issue 2, February, pp: 908-915, (2018).
- Feriyanto, N., Imbalanced relationship between regional economic growth and Income Per capita: An empirical analysis in Yogyakarta special province, *International Journal of Applied Business and Economic Research*, Vol. 14, No. 10, p. 6739-6754, (2016a).
- Feriyanto, N., The influence of Government Spending to the provinces' Gross Regional Domestic Product (GRDP) in Indonesia, *International Journal of Applied Business and Economic Research*, Vol. 14, No. 13, p. 8835-8851, (2016b).
- Garbarino, E., and Johnson, M. S., "The Different Roles of Satisfaction, Trust, and Commitment in Customer Relationships", *Journal of Marketing*, 63 (2), p. 70-87, (1999).
- Hair Jr., Anderson R.E., Tatham R.L., and Black W.C., "Multivariate Data Analysis," *New Jersey: Prentice-Hall International, Inc* Hawkins D.I., Best, (1998).
- Haryono, S., Kustiyadi, G., El Qadri, Z.M., and Muafi., Analysis of Domestic Tourist Market, *Journal of Environmental Management and Tourism*, Vol.8, Issue 8 (24) Winter, pp. 1591-1598, (2017).
- Horner, S., and Swarbrooke, J., "Consumer Behaviour in Tourism". *Elsevier*. Netherland, (2007).
- Hsiao, K.L., Lin, J.C.C., Wang, X.Y., Lu, H.P., and Yu., "Antecedents and Consequences of Trust in Online Product Recommendations: An Empirical Study in Social Shopping", *Online Inform. Rev.* Vol 34, pp: 935-953, (2010).
- Hsu, C., Killian, L., Graham, B., Gross, M.J., and Huang, S., "Tourism Marketing". *Milton Qld: John Wiley & Sons*. Australia, Ltd, (2008).
- Jianqiong, Y., Deng, J., Pierskalla, C., and King, B., "Urban Tourism Attributes and Overall Satisfaction: An Asymmetric Impact-Performance Analysis", *Urban Forestry & Urban Greening*. Volume 30, pp: 169-181, (2018).
- Kim, D. J., Ferrin, D. L., and Rao, H. R., "A Trust-based Consumer Decision-Making Model in Electronic Commerce: The Role of Trust, Perceived Risk, and Their Antecedents". *Decision Support System*, Vol.44, pp: 544-564, (2008).
- Koufaris, M., and Hampton-Sosa, W. (2004). "The Development of Initial Trust in an Online Company by New Customers", *Information & Management*. Vol. 41, pp: 377-397.
- Kurowska-Pysz, J., "Assessment of Trends for the Development of Cross-Border Cultural Clusters at an Example of Euroregion Cieszyn Silesia". *Forum Scientiae Oeconomia* 3(1), pp. 31-51, (2015).
- Middleton, V.T.C., Fyall, A., Morgan, M., and Rachhod, A., "Marketing In Travel And Tourism". Fourth edition. Great Britain. Elsevier Ltd., (2009).
- Morgan, R.M. and Hunt, S.D., "The Commitment-Trust Theory Of Relationship Marketing", *Journal of Marketing*, Vol. 58 No. 3, pp. 20-38, (1994).
- Muafi., From Company Reputation To Environmental Performance: The Context Of CSR Port Manager In Indonesia, *Journal of Environmental Management and Tourism*, Vol.8, Issue 7 (23) Winter, pp. 1386-1398, (2017).
- Nguyen, T. D., Barrett, N. J., Miller, K. E., Barrett, N. J., and Miller, K. E., "Brand Loyalty in Emerging Markets", *Marketing Intelligence & Planning*. Vol. 29, pp: 222-232, (2011).
- Oliver., "Measurement and Evaluation of Satisfaction Process in Retail Setting." *Journal of Retailing*, Vol. 57 (Fall), pp: 25- 48, (1981).
- Oliver, "Satisfaction: A Behavioral Perspective on the Consumer". New York: The McGraw-Hill Companies, Inc., (1997).
- Oppermann, M., "Tourism Destination Loyalty", *Journal of Travel Research*, Vol. 39, pp: 78-84, (2000).
- Roostika, R., and Muafi., The Role of Source Credibility and Place Attachment in Enhancing Visitors' Satisfaction, *JurnalManajemenTeknologi*, Vol. 13 No. 3, p. 239-252, (2014).
- Salo, J., and Karjaluo, H., "Mobile Games as an Advertising Medium: Towards a New Research Agenda". *The International Research Journal Innovative Marketing*, Vol. 3 (1), pp: 72-83, (2007).
- Simarmata, J., Keke, Y., Veronica, Silalahi, S.A., Benková, E., How to establish customer trust and retention in a highly competitive airline business. *Polish Journal of Management Studies*, 16 (1), pp. 202-214, (2017).
- Singh, J., and Sirdeshmukh, D., "Agency and Trust Mechanisms in Relational Exchanges," *Journal of the Academy of Marketing Science*, Vol. 28 (Winter), pp: 150-167, (2000).
- Slusarczyk, B., Smolag, K., Kot, S., The supply chain of a tourism product. *Actual Problems of Economics*, 179 (5), pp. 197-207, (2016).
- Štefko, R., Bačík, R., Fedorko, R., City marketing and its impact on income sources of the local government. *Polish Journal of Management Studies*, 15 (1), pp. 244-254, (2017).

- Sugandini, D., Wendry, B., and Muafi., "Influence of Quality Relationship and Satisfaction on Loyalty: Study on Supplier in Indonesia", *Journal of Business & Retail Management Research*. Vol-11, Issue 4, October 2017. Pages: 46-51, (2017a).
- Sugandini, D., Rahatmawati, I., and Istanto, Y., "Adoption of Natural Dyes for Batik Artisans in Yogyakarta, Indonesia", *Review of Integrative Business and Economics Research*, 6(1), 349-359, (2017b).
- Sugandini D., Sudiarto., Surjanti, J., Maroah, S., and Muafi., "Intention to delay: The context of technology adoption based on android", *International Journal of Civil Engineering and Technology*, Vol 9, Issue 3, p. 736-746, (2018a).
- Sugandini D., Purwoko., Pambudi, A., Resmi, S., Reniati., Muafi., and Kusumawati, R.A, "The Role of Uncertainty, Perceived Easy of Use, and Perceived Usefulness Towards the Technology Adoption", *International Journal of Civil Engineering and Technology*, Vol 9, Issue 4, p. 660-669, (2018b).
- Sugandini, D., Mujanah, S., Sudiarto., Indah, P.N., Priyadi, U., and Muafi., "The effect of integrated marketing communication, environmental responsibility and voluntariness toward electricity saving behavior intention", *International Journal of Civil Engineering and Technology*, Vol 9, Issue 4, p. 86–95, (2018c).
- Sugandini D., Rahatmawati, I and Arundati R, "Environmental Attitude on the Adoption Decision Mangrove Conservation: An Empirical Study on Communities in Special Region of Yogyakarta, Indonesia", *Review of Integrative Business and Economics Research*, Vol. 7(s1), 266-275, (2018d).
- Sugandini, D., "Anteseden Loyalitas Konsumen pada Industry Perhotelan (Studi Pada Hotel Berbintang di Daerah Istimewa Yogyakarta)", *Wahana*, Vol. 6 (2), pp. 181–200, (2003).
- Sugandini, D., and Djawoto., "The Influence of Advertising, Knowledge, and Attitudes towards Electricity-Saving Behavior", *Review of Integrative Business and Economics Research*. Vol. 7, Supplementary Issue 3. Hal 172-180, (2018).
- Susilowati, C., and Sugandini, D., "Perceived Value, eWord-of-Mouth, Traditional Word-of Mouth, and Perceived Quality to Destination Image of Vacation Tourists". *Review of Integrative Business and Economics Research*, Vol. 7(s1), pp: 312-321, (2018).
- Wahab, S. and Pigram, J.J., "Tourism and Sustainability: Policy Considerations". In S. Wahab and J.J. Pigram (eds) *Tourism, Development and Growth: The Challenge of Sustainability* (pp. 277–290). London and New York: Routledge, (1997).
- Ward, C., and Berno, T., "Beyond Social Exchange Theory: Attitudes Toward Tourists", *Annals of Tourism Research*. Volume 38, Issue 4, October, pp: 1556-1569, (2011).
- Wróblewski, Ł., Dacko-Pikiewicz, Z., Cuyler, A.C., The European union consumer behaviour in the festivals market in Poland. *Polish Journal of Management Studies*, 16 (2), pp. 302-314, (2017).
- Wu, C.-W., "Destination Loyalty Modelling of The Global Tourism", *Journal of Business Research*. Vol.69 No.6 pp.2213-2219, (2016).
- Wu, T-C., Xie, P. F., and Tsai, M.-C., "Perceptions of Attractiveness for Salt Heritage Tourism: A Tourist Perspective", *Tourism Management*, Vol. 51, pp: 201–209, (2015).
- Yu, Y. T., and Dean, A., "The Contribution of Emotional Satisfaction to Consumer Loyalty", *International Journal of Service Industry Management*, Vol. 12(3), pp: 234-250, (2001).
- Yung-Yeh, S., and Li, Y-Ming, "Building Trust in m-Commerce: Contributions from Quality and Satisfaction", *Online Information Review*, Vol. 33 Iss: 6 pp. 1066 – 1086, (2009).



# Business strategy, organizational structure, work processes: are the alignment?

Muafi<sup>a</sup>, Janusz Grabara<sup>b\*</sup>, Sudiyarto<sup>c</sup>, Yuni Siswanti<sup>d</sup>

<sup>a</sup>Management Department, Economic Faculty, Universitas Islam Indonesia

<sup>b</sup>The Management Faculty, Czestochowa Univeristy of Technology

<sup>c</sup>Agribusiness Department, Agriculture Faculty, Universitas Pembangunan Nasional “Veteran” Jawa Timur

<sup>d</sup>Management Department, Economic Faculty and Business Faculty, Universitas Pembangunan Nasional “Veteran” Yogyakarta

---

## Abstract

The development of digital creative industry in Yogyakarta Special Province (DIY), Indonesia is growing rapidly. This condition is supported by the emergence of other businesses such as hotels, culinary, fashion, furniture and other creative industries. Beside that DIY known as education city. The purpose of study is examine and analyze the level of business strategy alignment which implemented by digital creative companies in DIY and associated with organizational structure and work processes. Population in this study is leader/manager of digital creative industry company in DIY with sample size target is 200 respondent. After conduct an identification, the respondents who answered the questionnaire completely are 172 respondents. Statistical technique uses *euclidean distance (ED) regression*. The result concludes that there is an alignment between; (1) business strategy (prospector-defender) with organizational structure (organic-mechanic) and work processes (non routine-routine) both in contingency and configuration, (2) prospector strategy with organic structure and non routine work processes both in contingency and configuration, and (3) defender strategy with mechanic structure and routine work processes both in contingency and configuration.

**Keywords:** *business strategy; organizational structure; work processes; alignment.*

---

## 1. Introduction

Nowadays, the globalization era makes company must be able to take the challenges and capture the opportunities. The world seems limitless and the science and technology development are unstoppable. There are many ways taken by the company to become a successful company. The automation process, education and training, quality improvement of management, and redesign the organizational structure within the company are the various ways that company can use to save from failure. However, these methods require high costs and sometimes in efficient (April et al., 2006; Kandemir, 2006). The company must be careful in designing and finding business models which implement the appropriate business strategy and should be in accordance with internal and external organization's conditions so the company does not fail. The organization of fit theory states that organizational strategy must be compatible with other factors in order to achieve improved business performance (Galbraith and Nathanson, 1978; Homburg et al., 1999). Therefore, to make an organization has an increasing performance continuously, it is necessary to have an organizational structure and work processes align with the business strategy which implemented by the company.

This study is focused on the digital creative industry which currently grows rapidly in Yogyakarta Special Region (DIY), Indonesia. The digital creative industry is a group of companies that always being dynamic and follow very high and volatile market's demand changes. Digital business in DIY is dominated by software house (21.05%), followed by commerce players (11%), fintech (10%), and digital agency (8%). However, other categories such as travel, education, game house and IoT still can be found. The startup size is majority driven by 2-5 people (36.84%) while the others are single player (14.04%) (<https://dailysocial.id/post/temuan-menarik-tentang-startup-di-yogyakarta-tahun-2017>, accessed

---

\* Corresponding author

E-mail address: [janusz@grabara.eu](mailto:janusz@grabara.eu)

on May 10, 2018). IT companies are competing each other. Every year, new IT companies appear inside and outside DIY and even from abroad. This competition should be considered as a good opportunity so that each company will be motivated to have superior performance compared to its competitors. The purpose of this study is to test and analyze the alignment between business strategy, organizational structure, and work processes of digital companies in DIY. The alignment concept uses the ideal relationship of typology that has extreme continuum differences and being analyzed from the aspect namely: business strategy (prospector Vs defender), organizational structure (organic Vs mechanic) and work processes (non routine Vs routine). The impact is if there is an alignment business strategy with contingency variables such as organizational structure and work processes, it will be able to improve business performance increasingly.

## **2. Literature review and hypotheses. Business strategy, organizational structure and work processes**

Organizational strategy typology that used in this study refers to competitive strategy proposed by Miles et al. (1978) namely; prospector and defender. The prospector strategy has characteristics; always wanted to be a pioneer in the creation of new products/services, emphasize innovation and creativity, doesn't care with the efficiency, find and earn external resources expansively, and environmental uncertainty are very high. While the defender strategy has characteristics; concern with efficiency, maintain and protect market share from new competitors, require formalities and centralization, rarely to innovate and environmental uncertainty easy to predict (Muafi, 2009a). Kumar, et al. (1997) says that Miles and Snow's strategy is similar to Porter's generic strategy (differentiation and cost leadership). Prospector (Miles and Snow) is similar to Differentiation (Porter). Defender (Miles and Snow) is similar to cost leadership (Porter). Cost Leadership and Differentiation are mutually exclusive. If both are combined, there will be stuck in the middle because they are contradictory but if each strategy is combined with a focused strategy then Hybrid will occur. It does not mean that stuck in the middle conditions cannot happen. Hlavacka, et al. (2001) adds that 'Porter's generic strategies are not mutually exclusive and each strategy can be linked to other various strategies' (Muafi, 2009a, Muafi, 2009b). This study uses two typologies of organizational strategy prospector and defender because these two types of strategies have firm characteristics so they can be used to deal with the demands of external environment (Doty et al., 1993; Muafi, 2009a). The two of internal organizational variables that should have align with organizational strategy is the organizational structure and work processes within the organization.

The changing business environment requires organization must be able to design their organizational structures efficiently and effectively. This is important because it involves individuals and groups behavior within the organization. Robbins (1990) and others authors (Steers, 1977, Muafi, 2009a, Szczepańska-Woszczyna, 2014, Pacana and Ulewicz, 2017) recommend when managers design an organizational structure, there are several points to consider, including; job specialization, departmentalization, chain of command, span of control, centralization, and formalization. The change of business strategy in the company requires company to make adjustment with organizational structure and other contingency variables that affect the achievement of business performance (Muafi, 2009a, 2009b, Kovács, 2017, Shpak, et al., 2017). The previous studies have concluded that companies that have organic structure will be alignment with the prospector strategy, and companies with mechanical structure will be alignment with the defender strategy, which will enhance the company's performance (Muafi, 2009a, Robertson and Chetty, 2000). The mechanical structure emphasizes the importance of achieving high-level production and efficiency, formality, the low specialization of the labor force, and the presence of centralization. While the organic structure emphasizes the importance of achieving adaptation, flexibility, specialization of labor amount and high-level centralization. This organization's design less rely on existing rules and procedures (Robbins, 1990; Robertson and Chetty, 2000; Muafi, 2009a). Chandler (1962; Kavele, 2012) says that the organizational structure should follow the organization's strategy because the organization's strategy is the direction to achieve the goal and must be supported by the organizational structure. The organizational structure must be integrated with the company's strategy to achieve the organization's vision, mission, and goals.

Related with work processes, Garcia (2014) simply defines a "process is a series of actions or activities that combine to achieve an end or outcome". Work processes is very important process in the process of creating the internal value of a product/service which offered by the company. The working process include product design and delivery, customer support, supply chain management, business, and support from multiple processes. This condition requires core competencies of the organization in order to have a relative success compared to competitors who are all oriented to customers, stakeholders and stockholder value ([http://www.baldrige21.com/BALDRIGE\\_GLOSSARY/BN/Work\\_Processes.html](http://www.baldrige21.com/BALDRIGE_GLOSSARY/BN/Work_Processes.html), accessed on May 10, 2018). According to Ringrose (2018, in <https://www.promapp.com/resources/10-best-management-practices-for-work-processes/> accessed on May 10, 2018), there are some management practices that can conduct to improve the work processes, such as; (1) design and document core processes, (2) monitor and control the control process to ensure service standards to be consistent; (3) monitor and control the control process to ensure the service standard system to be consistent (eg quality, work environment, health & safety; (4) anticipate or adapt to changes, (5) take corrective action when problems occur; (6) prevent recurrence of problems when there are process changes; (7) analyze the process regularly and make changes which aimed at continuous improvement; (8) communicate the process changes to all employees who involved in the process; (9) involve the customers, suppliers, and/or partners in designing and analyzing processes; and (10) use the external data to compare performance with other organizations.

Garcia (2014) adds that when the work processes is consistent or systematic, the characteristics of the result will be more predictable and controlled. If this condition occurs, the work processes performance quality will be easily guaranteed, so it will be able to improve the growth and sustainability of the company's business. Working process requires different tasks and expertise/skills. Garcia (2014) suggests that work processes in business should be mapped. It is important because it will be useful for; (1) understand the entire flow process, if no one has a complete view, (2) facilitate new employees, (3) identify improvement in response to external or environmental threats, (4) identify improvement of project targets which need to be improved, (5) understand the stakeholders, market share, or supply chain impacts in strategic planning, (6) provide insight into new functions about how work is conducted, (7) identify quality control issue to understand better and improve the process, and (8) require mapping process from organizational functions and processes on merger and acquisition activities.

Kandemir (2016) concludes that the outcome of the work processes relies heavily on the tasks assigned to the employees. Managers must select employee's competency to fit their workload to minimize the average duration of a work process while keeping employees below the workload threshold to prevent errors caused by overloading. This is important for organizations to improve performance, manage excessive workloads, and produce a satisfactory environment for employees, without modifying the structure of a work processes itself (Kandemir, 2006; Kamrani et al., 2012, Smolağ, et al., 2015, Ğuríková and Seková, 2016). Valle et al. (2000) divides the work processes with two extreme approaches namely routine and non-routine work processes. Routine work processes is characterized; repetitive and predictable, cooperation and interdependency, demand quality standard, require to take decisions involving risk, application of little expertise and skill. While non-routine work processes is characterized; creative and innovator, long term results, autonomy, undemanding, no risk, considerable expertise and skill needed. Valle et al. (2000) conclude that routine work processes tend to adopt mechanical training models that use defenders strategies, whereas non-routine work processes tend to adopt organic training models that employ prospectors strategies.

*H1. By contingency, the higher the level of business strategy alignment (prospector-defender) and organizational structure (organic-mechanic), the higher the business performance, vice versa (bivariate fit).*

*H2. By contingency, the higher the level of business strategy alignment (prospector-defender) and work processes (non routine routine), the higher the business performance, vice versa (bivariate fit).*

*H3. By configuration, the higher the level of business strategy alignment (prospector-defender) with organizational structure (organic-mechanic) and work processes (non-routine), the higher the business performance, vice versa (multivariate fit).*

*H4. By contingency, the higher the alignment level of the prospector strategy and the organic structure, the higher the business performance, vice versa (bivariate fit).*

*H5. By contingency, the higher the level of alignment of the prospector strategy and non routine work processes, the higher the business performance, vice versa (bivariate fit).*

*H6. By configuration, the higher level of alignment of prospector strategy with organic structure and non routine work processes, the higher the business performance, vice versa (multivariate fit).*

*H7. By contingency, the higher the level of alignment of the defender strategy and the mechanical structure, the higher the business performance, vice versa (bivariate fit).*

*H8. By contingency, the higher the level of alignment of the defender strategy and the routine work processes, the higher the business performance, vice versa (bivariate fit).*

*H9. By configuration, the higher the level of alignment of the defender strategy with the mechanic structure and the routine work processes, the higher the business performance, vice versa (multivariate fit).*

### 3. Research methods

This study was conducted on digital creative industry in DIY Province, Indonesia. The number of digital creative companies in the DIY region is huge and always growing. The population in this study is the overall leader/manager of digital creative company in DIY. The sample size is targeted to 200 leaders/managers and chosen purposively. After the identification, the total of respondents who answer the questionnaire completely is 172 leaders/managers. This study uses a system approach by analyzing the effect of ideal type alignment of business strategy variables (BS) (prospector Vs defender), organizational structure (OS) (organic Vs mechanic) and work processes (WP) (non-routine Vs routine) related with business performance (BP) (Van de Ven and Drajin, 1985; Muafi, 2009a; Muafi, 2009b; Selto and Renner, 1995). The business performance in this study is based on the perception of the leaders/managers on the company's performance which they lead compared to the average industry of similar companies with indicators; ability to gain profit in the long term, sales growth, job satisfaction, organizational capability, work adaptation and service quality. Statistical technique using euclidean distance (ED) regression and one way Anova with SPSS software. The uniqueness of the ED regression is the greater the ED score means the alignment between the variable is smaller (the distance between the variables is closer) so that it will negatively affect the performance, and vice versa. In this case, the number of regression coefficients sought is negative and significant. While, one-way Anova is used to analyze the differences of business strategy group between prospector and defender. The scale of measurement of organizational structure variable and work processes is using semantic scale with score 1-7. This scale is recommended for two different typologies (Cooper and Schindler, 1997, Muafi, 2009a, Muafi, 2009b). For business performance, researchers are using Likert

scale with score 1 (very low) to 7 (very high). The result of the whole respondents is organisations that used the prospector strategy (code 1) was 111 companies (mean score  $\geq 3.5$ ), while the rest (average score  $< 3.5$ ) of 61 organisations using defender strategy (code 2). The result of calculation with one way Anova is significant F value (sign = 0.000), it means there is significant difference between group of prospector strategy and defender. The results of validity and reliability test item questionnaire of all variables are valid and reliable.

#### 4. Research results

Majority the leaders/managers have Bachelor degree (52%), the business form is CV (53%), have 5-10 employees (61%), and using their own funds for establishment and management (56%).

##### **Regression Analysis for Overall Strategy (Prospector and Defender)**

The result of t test in Table 1 turns out to conclude that the significance  $< 0.01$  so that hypothesis to 1 till 3 is accepted.

Table 1. Overall strategy test results (Prospector and Defender n = 172)

Regression Equation Model	Coefficients (B)	Std Error	t	Sign	Decision
$Y = a + b \text{ dist (OS.BS)+e}$	-.591	.069	-8.57	0.001	H1 accepted
$Y = a + b \text{ dist (WP.BS)+e}$	-.367	.051	-7.19	0.000	H2 accepted
$Y = a + b \text{ dist (OS.WP.BS)+e}$	-.441	.038	-11.60	0.002	H3 accepted

Similarly, the t test results in Tables 2 and 3 yield the same conclusion that the significance  $< 0.01$  so that the hypothesis to 4 to 9 is accepted.

Table 2. Prospector strategy test results n = 111

Regression Equation Model	Coefficients (B)	Std Error	t	Sign	Decision
$Y = a + b \text{ dist (OS.BS)+e}$	-.411	.081	-5.07	0.003	H4 accepted
$Y = a + b \text{ dist (WP.BS)+e}$	-.225	.023	-10.22	0.000	H5 accepted
$Y = a + b \text{ dist (OS.WP.BS)+e}$	-.247	.041	-6.02	0.000	H6 accepted

Table 3. Defender strategy test results n = 61

Regression Equation Model	Coefficients (B)	Std Error	t	Sign	Decision
$Y = a + b \text{ dist (OS.BS)+e}$	-.122	.052	-2.35	0.005	H7 accepted
$Y = a + b \text{ dist (WP.BS)+e}$	-.247	.033	-7.48	0.000	H8 accepted

#### 5. Discussion

It is known that the whole hypotheses is accepted. The findings proved that there is alignment between business strategy both prospector and defender with organizational structure and work process. It is indicate generally that these findings support the contingency and configuration approach. This result also supports the research and opinion of Delaney and Husehild (1996; Richardson and Thompson, 1999; Priyono, 2004) that is 'a successful strategy relies on external or vertical and internal/horizontal compliance' which must complement and encourage each other. In the implementation of business strategy (prospector and defender) it turns out the company has been consistent in designing the organizational structure and work processes that exist. Business performance will increase when organizational structure both organic and mechanic in accordance with selected business strategy. It is also applies to non-routine and routine work processes. It is proven that the growth of digital industry in DIY is increasing from year to year, there are even foreign companies that compete in the industry. This indicates that its market share is still wide open for both new players (start up) and old players.

Further, both the prospector and defender strategy respectively, it was found that there is a match between the prospector strategy with organic structure and non routine work processes, vice versa. This result supports Robertson and Chetty's finding (2000, Muafi, 2009a; Valle, et al., 2000). It should be remembered that the configuration model in organizational fit theory says that "if there is a corresponding relationship between organizational strategy, organizational structure, system and organizational culture, it will be able to reduce internal barriers for the organization to have superior performance" (Galbraith and Nathanson, 1978; Priyono, 2004). Similarly, it was found that contingency with the choice of organic structure and non routine work processes has been in accordance with the prospector strategy that has been implemented by the company. It is reasonable given the level of intense competition makes them have to act quickly and aggressively without considering the formalization, rules, procedures that exist, and the centralization of authority. However in a different perspective, it was found from the interview's results with some of the leaders of the company that the tightness of the existing level of competition makes them need to be careful in making decisions related to business run. They remain guided by high-level production and efficiency, formality, rules and centralization because they generally fund their own business (self-funded = 56%), business stages are still in the level of product development (51%) rather than market development, and have not been dare to follow the trend

because they still have business as usual principle (52% ). These results reinforce study findings from Jogja start.up (<https://dailysocial.id/post/temuan-menarik-tentang-startup-di-yogyakarta-tahun-2017>, accessed on May 10, 2018). The results also reinforce the study findings of Valle et al. (2000) that routine mechanical structures and work processes are more subject to them because they are in line with the defender business strategy which implemented. They are more concentrate on systematic and routine work processes as well as patterned and align with the employee skills. All are oriented for long-term profit improvement, sales growth, job satisfaction, organizational capability, work adaptation, and service quality.

## 6. Theory and managerial contributions

This study has contribution to theory namely; (a) the organization needs to approach the ideal type of configuration and contingency between the business strategy-the contingency variable (organizational structure-work processes) so that further can improve the overall business performance, (b) the organization needs to be consistent in implementing the strategy by considering other factors in internal management organization to achieve more business performance and (c) difference strategy election will influence difference perception of company leaders to contingency variable which influenced it. While this study gives managerial contribution, such as; (a) management should pay attention to strategic issues affecting the company's business strategy to boost its performance. The strategic issues must be identified and analyzed then adapt with their business strategy, so as it can improve their business performance, and (b) need to design the right organizational structure and work processes so that the company can be more effective and efficient in operating and oriented to the achievement of its business performance.

## 7. Limitations and future research

This study does not distinguish the form of business entity so that sometimes the perception of respondents to the variable still requires detailed explanation and intensive mentoring because the level of leaders/managers education diverse so it can confusing in perceiving the submitted questionnaire. Besides that, this study uses static approach because it does not examine the strategy change from time to time, so it is necessary to consider the dynamic approach using longitudinal study although it requires high cost and long time (Priyono, 2004). In the framework of organization fit theory, there are many other variables that can be considered in models such as environmental uncertainty, HR practices, organizational culture, role behaviors, and other contingency variables.

## References

- April, J., Better, M., Glover, F., Kelly, J., & Laguna, M. (2006). *Enhancing business process management with simulation optimization*. Paper presented at the Simulation Conference, 2006. *Proceedings of the Winter*, 3-6 Dec, Publisher IEEE.
- Chandler, A. (1962). *Strategy and Structure: Chapters in the history of industrial enterprise*, Doubleday, New York.
- Cooper, D.R., & Schindler, P. S. (2014). *Business Research Methods*. Twelfth edition, New York, NY : McGraw-Hill/Irwin.
- Delaney, J.T., & Husehild, M.A., 1996. The Impact of Human Resources Management Practices on Perceptions of Organizational Performance, *Academic of Management Journal*, 39(4), 949-969.
- Doty, D.H., Glick, W.H., & Huber, G.P. (1993). Fit, equifinality, and organizational effectiveness; a test a two configurational theories, *Academy of Management Journal*, 36, 1196-1250.
- Đuríková, V., Seková, M. (2016). Human Resource Management Creativity in Companies Operating in Intercultural Environment. *Forum Scientiae Oeconomia*, 4(2), pp. 59-67.
- Galbraith, J.R., & Nathanson, D.A. (1978). *Strategy implementation: the role of structure and process*. St. Paul: West Pub. Co.
- Garcia, D. (2014). *Work Processes Focus. Let's Achieve Your Excellence!*, Pursuit of Excellence LLC, January, 1-7.
- Hlavacka, S., Bacharova, L., Rusnakova, V., & Wagner, R. (2001). Performance implication of Porter's strategies in Slovak hospitals, *Journal of Management in Medicine*, Vol. 15, No. 1, pp. 44-66.
- Homburg, C., Krohmer, H., & Workman Jr, J.P. (1999). Strategic Consensus and Performance: The Role of Strategy Type and Market-Related Dynamism, *Strategic Management Journal*, 20, p. 339-357.
- Kamrani, F., Ayani, R., & Moradi, F. (2012). A framework for simulation-based optimization of business process models. *Simulation*, 88(7), 852-869.
- Kandemir, C. (2016). *Improvement of Work Process Performance with Task Assignments and Mental Workload Balancing. Engineering Management & Systems Engineering. Theses & Dissertations*. 10, Old Dominion University.
- Kavele, S. (2012). The Connection Between Strategy and Structure, *International Journal of Business and Commerce*, 1(6), february, p. 60-70.
- Kovács, G. (2017). Global economic changes, optimization of virtual enterprises - Software development. *Polish Journal of Management Studies*, 15 (2), pp. 115-131.

- Kumar, K., Subramanian R., & Yauger, C. (1997). Pure versus Hybrid: Performance Implications of Porter's generic Strategies, *Health care Management*, Fall, pp. 47-60.
- Miles, R.E., Snow, C.C., Meyer, A.D., & Coleman, Jr., H.J. (1978). Organization Strategy, Structure and Process. *Academy of Management Review*, Vol. 3, No. 3 (Jul., 1978), pp. 546-562.
- Muafi. (2009a). A Configuration And Contingency Approach To Understanding Export Performance, *International Review of Business Research Papers*, Vol.5 NO. 2 March 2009 Pp. 358-369.
- Muafi. (2009b). The effects of alignment competitive strategy, culture, and role behavior on organizational performance in service firms, *International Journal of Organizational Innovation*, 2 (1), Summer, p. 106-134.
- Pacana, A., Ulewicz, R. (2017). Research of determinants motivating to implement the environmental management system. *Polish Journal of Management Studies*, 16 (1), pp. 165-174.
- Priyono, B.S. (2004). Pengaruh Derajat Kesesuaian Hubungan Strategi, Struktur, Sistem Karir dan Budaya Organisasi Terhadap Kinerja. *Disertasi*. Universitas Gadjah Mada Yogyakarta.
8. Richardson, R., & Thompson, M (1999) *The Impact of People Management Practices on Business Performance: A literature review*, Institute of Personnel and Development, London.
- Robbins, S.P. (1990). *Organization Theory: Structure, Design and Application*. Prentice Hall, Inc. A Division of Simon & Schuster Englewood Cliffs, N.J. 07632.
- Roberston, C., & Chetty, S.K. (2000). A Contingency Based Approach to Understanding Export Performance, *International Business Review*, 9, p. 211-235.
- Selto, F. H., & Renner, C.J. (1995). Assessing The Organizational Fit Of A Just In Time Manufacturing System; Testing Selection, Interaction and System Models Of Contingency Theory, *Accounting Organizations and Society*, Vol. 20, No. 7/8, p. 665-684.
- Shpak, N., Satalkina, L., Sroka, W., Hittmar, S. (2017). The social direction of enterprises' innovation activity. *Polish Journal of Management Studies*, 16(1), pp. 187-201.
- Smoląg, K., Kot, S., Oane-Marinescu, C.M. (2015). Contemporary conditions of engineers education process management, *Polish Journal of Management Studies*, 11 (2), pp. 149-159.
- Steers, R.M. (1977). *Organizational Effectiveness, A Behavioral View*, Goodyear Publising Company, Inc ., Santa Monica, California.
- Szczepańska-Woszczyna, K. (2014). The importance of organizational culture for innovation in the company. In: *Forum Scientiae Oeconomia*. 2(3) pp. 27-39
- Valle, R., Martin, F., Romero, P.M., & Dolan, S.L. (2000), Business Strategy, work processes and human resources training: are the congruent?, *Journal Of Organizational Behavior*, 21, p. 283-297.
- Van de Vend, A.H., & Drazin, R. (1985). The Concept of Fit in Contingency Theory, *Research in Organizational Behavior*, 7: p. 333-365.
- [http://www.baldrige21.com/BALDRIGE\\_GLOSSARY/BN/Work\\_Processes.html](http://www.baldrige21.com/BALDRIGE_GLOSSARY/BN/Work_Processes.html), acccesed on May 10, 2018.
- <https://dailysocial.id/post/temuan-menarik-tentang-startup-di-yogyakarta-tahun-2017>, accessed on May 10, 2018.
- <https://www.promapp.com/resources/10-best-management-practices-for-work-processes/> acccesed on May 10, 2018.

## Some considerations on management internal control of stocks in the field of construction societies

Răvaș Bogdan\*

*University of Petrosani, University Str, no. 20, Petrosani, Romania*

---

### Abstract

Lately, dependence has become a reality between the need for information, the existence of a system that ensures their delivery and the development of society in general.

The system that can provide the required information is the information system, for which the technique and differentiated means are used depending on the type of system to be built, the level of development of the company from the economic and informational point of view.

The development of computerized electronic systems has made it possible to replace traditional primary documents with technical information carriers that fulfill both the role of primary documents and those of technical data support necessary for their further processing.

Improving inventory evidence leads to increased productivity growth, and the improvement of the information system is in fact the essential element for the transition to a new quality throughout the economic activity.

*Keywords:* control, management, stocks, accounting, information, decision

---

### 1. Literature review

In order to complete this paper I have used also internal and external literature sources composed by books, papers, articles written by some more or less known authors in the field. I have taken and developed some of their ideas in order to reach the purpose of this study, meaning to underline the importance of the internal audit also in the field of construction companies.

### 2. Research methodology

The qualitative research methodology was utilized in this study. The study started with a thorough analysis of the current internal audit methodology and practice. Next, best practices on the areas of problem were gathered and analyzed based on a literature review and on the author's previous papers concerning similar problems. Based on the results of the best practices review and considering also the objectives of the internal audit function, solutions to the problem were constructed.

### 3. The base of the research

A significant feature of inventories is that they go through a continuous cycle of acquisition, use in production and sales. In both cases, the producer and trader, the inventories and the cost of sales are significant both for the financial statements of synthesis and for the appreciation of the achieved performances.

There are many risk factors that can affect stocks, including:

---

\* Corresponding author. Tel.: 0040721521866;.  
E-mail address: ravasbogdan@yahoo.com.



- the volume of procurement, production and sales transactions is generally high, thus increasing the risk of errors in accounts;
- there are always non-violet points with regard to inventory valuation, such as identification, sizing and allocation of indirect costs, accounting for residual products, estimation of deviations from standard costs, correct allocation of costs for the manufacture of complementary products, etc.
- special procedures are sometimes required to determine the quantity or value of inventories, such as the valuation of inventories by other experts;
- stocks are often stored in different places, creating difficulties both in controlling them to prevent theft or physical degradation and in accounting for stocks in transit;
- stocks are vulnerable to changes of the economic circumstances that may lead to a reduction in demand, sales and, therefore, the application of different treatments in such cases for their assessment;
- stocks may be subject to return contracts (for example, packaging).

#### **4. The need for management internal control of stocks in the field of construction companies**

In planning of the inventory management process, we need to be aware of the high risk of management's claims regarding the existence and stock valuation. As regarding the assets, the company management is motivated to overestimate inventories rather than underestimate them. Due to the non-existence of third parties in the case of production stocks, as is the case with construction companies, it is much easier to overestimate the value of stocks than in the case of other assets such as receivables, treasury, etc.

Preventive measures to mitigate the impact of risks on stock records at the disposal of the manager of the economic entity

In the case of a satisfactory managerial control system in operation, the following activities must be controlled:

- stock purchases;
- storage of stocks;
- exit from inventory management;
- determining the existence, physical integrity and rights of the stocks;
- inventory valuation.

Determining the moment when the transfer of rights to inventory from supplier to client is taking place is very important. There are situations in which stocks are transferred with or without property rights over them. From this point of view, we must appreciate the existence of effective controls on this type of transaction.

Depending on the nature of the stocks held in construction societies, the storage conditions, as well as the security conditions must be checked. The type of stock control storage as well as the security conditions will be different for company profile stocks.

In addition to direct control, in such cases, it is expected that restrictions on the exit of the respective assets will be in force - leaving the management on the basis of duly authorized documents. In addition, stockpiling should be done under appropriate conditions to prevent damage, destruction, and facilitate access and stock identification.

Control of exit from inventory management is often demonstrated by strict procedures (documentation) (which must be duly authorized) and assessment (in the case of the disposal of stocks that are difficult to sell for waste products, etc.).

Controlling the existence, physical integrity and rights of inventories requires the application of adequate physical inventory inspection procedures and conciliation of inventory results with accounting records followed by the investigation of inventory differences.

The existence of inventory differences (inventory pluses / minus) indicates a high risk. In addition to inventory availability, the inventory allows to determine the physical integrity of inventories and helps to identify exploitation rights on inventories.

Obtaining evidence of stock rights is more difficult, which leads to the need to apply additional control procedures. The basic principle retained for the valuation of inventories in the synthetic financial statements is to select the minimum cost between the cost and the net realizable value. Thus, all the controls exercised in this sphere of activity must ensure compliance with this principle. Particular attention should be paid to controlling deviations from the standard costs and the measures adopted to that end. Significant unplanned deviations may indicate a high control risk.

In order to verify management's statements in the financial statements about the existence and completeness of stock information, we must be able to choose a control strategy based on the company policy adopted to determine the amount of inventory held. The control strategies identified as possible in construction companies are the following:

- when inventories are accounted for by the permanent inventory method and the inventory is made close to the balance sheet date, the control strategy permits the control risk associated with inventory records to be relatively high;
- if inventories are determined quantitatively by inventory at the balance sheet date, the control strategy requires a predominant approach based on substantive procedures that does not test the control system applied to inventory accounting because it may be completely absent.

## **5. The determined internal control targets and risks in this area of activity**

A major focus is on verifying the existence and evaluation of stocks, given the inherent risk associated with these two allegations. In general, the risk of not being detected is assessed at a low level for the existence and valuation of inventories, while for the rest of the allegations of inventories, the risk of not being detected may be at higher levels to averages.

In order to verify the initial balances, we must ensure that all adjustments agreed in the previous year on the occasion of the control have been recorded. Moreover, especially in situations where inventories are accounted for by the intermittent inventory method, we need to verify that all inventory records are kept up to date and kept up to date.

The analytical procedures applicable to stocks are very varied. An analysis of trends at branch or sector level may be essential for the development of the program of analytical procedures that will be applied to assess the analytical information of the company.

Verification of records in stock accounts is based on supporting documents. Where, at the balance sheet date, inventories are determined solely on the basis of the intermittent inventory, the appropriate detail tests shall consist of:

- verification of the physical existence of the stocks through inspection;
- investigating significant differences between physical inventory results and stock records.

If the quantity of stocks is determined by counting (weighing, etc.) at a date other than the end of the financial year, adjusted by reference to the accounting records for the period up to the quantitative verification, the detailed tests may be applied only to the remainder of the financial year between the time of the quantitative verification and the closure of the exercise.

Testing for compliance with the independence of procurement and sales exercises is important for identifying transactions that have taken place near the end of the financial year and for checking how they have been attributed to the year to which they relate.

When inventories are of significant importance in the context of the company's financial statements and stock inventory is not impossible, inventory observation is one of the major management responsibilities.

Where there is insufficient evidence of the existence of the initial balances or when the physical inventory at the end of the financial year can not be found and when it can not obtain sufficient and appropriate evidence by applying alternative control procedures, we have to abstain from issuing a decisive opinion that we should pass into the control report.

Applying this procedure allows us to provide evidence of management's assertions in the financial statements about the existence, completeness, valuation and rights, respectively obligations on stocks.

After inventory, the company uses inventory lists to compile the inventory report. All items after being counted, weighed, etc. are then evaluated, and the results are the basis for the bookkeeping corrections. Due to the importance of inventory lists together with the inventory register, we must ensure that the inventory lists faithfully the outcome of physical inspection, both in quantitative and in terms of value.

To determine if inventory lists faithfully present inventory results, you must:

- compare our own test results with those included in the inventory lists;
- to identify the lists drawn up when the inventory was assisted and to check their compliance with the inventory register;
- compare the results of the inventory with the accounting records, identify and ask for explanations regarding the differences noted;
- check the calculations for determining the value of inventory items.

Verifying inventory valuation involves determining the cost of inventories and their net realizable value, as well as comparing the two values to keep the minimum in the synthetic financial statements.

In the case of stocks of finished products, finished products and semi-finished products, the cost has to be checked in the light of cost accounting. The calculation system used by the entity is assessed in principle during the interim control when applying tests on costing methods of production. If inventories in production are valued at standard cost, the variations recorded against it should be analyzed.

International Accounting Standards (in this case IAS 2) require that inventories be reflected in the balance sheet at net realizable value if it is lower than cost. The estimation of the net realizable value implies the use of accounting estimates, which means that we have to take into consideration the provisions of the accounting estimates that imply:

- analyzing and checking the estimation methods applied by management;
- the use of independent estimates;
- continuous analysis and review of further developments.

In the case of inventories valued at net realizable value, the method of calculation and net realization should be checked. In some situations, the starting point is the current value or the contract sale price, corrected for the sales / realization costs involved. In other situations, calculation formulas that take into account age, previous changes, and expected future changes to those stocks may be used. We need to examine the data and assumptions underlying the formulation of the estimates, verify the calculations, analyze the previous evolution of the stock, and verify that the estimates are properly approved by the management.

Regarding the inherent risk assessment through the under-valuation of inventory book value adjustments, we must apply the substantive procedures that allow us to identify the needs for further adjusting the inventory book value. IAS 2 retains the following situations in which the adjustment of inventories may be required: lowering the sales price; physical damage; perimeters; the decision to sell at a loss; purchase or production errors.

The specific procedures normally applied consist of:

- analysis of sales made after the balance sheet date;
- finding obsolete stocks during assisted inventory
- analysis of stocks held in relation to the scheduled turnover to determine the excess stocks;
- discussions with the company's management, sales and production staff;
- analysis of the minutes drawn up during the meetings of the Executive Board, etc.

If the assertions made in the financial statements about the value of inventories are related to complicated technical issues, the assistance of technical experts in the field may be required.

When stocks are deposited with third parties, we must obtain evidence of stock availability through direct communication with custodians. The application of this procedure may provide sufficient evidence, unless the amounts involved are not material in relation to the total assets or current assets. In such circumstances, we have to decide on the following procedures:

- assessing the integrity and independence of the custodian;
- assisting with the inventory of stocks in custody;
- obtaining and analyzing the report of a specialized person, if the latter has carried out the physical inspection of the stocks under custody;
- creditors' confirmation of warranties lodged as collateral for contracted loans.

The application of this procedure provides evidence of the assertions contained in the financial statements regarding the rights and obligations on the stocks. Similarly, the procedure may allow evidence to be provided of the completeness of inventory records if custodians confirm a quantity of stocks greater than that identified in the company's accounts.

Confirmation of stocks by the custodian does not provide any evidence of the value of the stored stocks, as the custodian does not have legal competence in this area.

There are situations in which companies can hold stocks that belong to their customers at their request, after the sale has taken place. Another possible situation is the purchase of stocks with either a return or a payment obligation if there is a subsequent sale. In this way, management will be required to separate the inventories of commodity stocks during inventory. In addition, a written confirmation of stock ownership is usually required.

In the reverse situation, management is asked to confirm the inventory of the company, but it is "recorded" to customers. For such cases, we need to look at the contracts we have agreed with third parties and ask them to confirm the quantity of "recorded" stocks.

In another possible scenario, stocks can be used as collateral for contracting credits. In this regard, we need to obtain information / explanations from the management on the existence of such credit agreements and verify the publication of additional relevant information in the notes to the financial statements.

Also, we must not ignore the creative accounting techniques applied at the stock level. Thus, recording a significant sales volume close to the end of the financial year to a customer who appears not to require the immediate delivery of the goods may hide an attempt to lower inventories and increase liquidity, leading to an erroneous picture of the calculated economic indicators based on this accounting information. Often, such techniques are followed by the acquisitions in the period immediately following the end of the financial year. Such transactions must be accounted for according to their economic substance: secured stock loans.

Through this procedure, we have the ability to provide proof of management's assertions in the financial statements about the rights and obligations on stocks, as well as the presentation of stock information in the annual accounts.

We also need to ensure that the main stock categories have been identified and grouped correctly in the financial statements. In addition, the notes to the balance sheet must provide additional information on: the methods used to determine the costs; stocks used as collateral; the existence of major procurement commitments.

Talks with the company's management are a commonly used procedure for determining whether there are constraints on future stock purchases based on third-party conventions. In the event that there are such restrictions, we must examine the contracts concluded and evaluate the honesty of the accounting and reports prepared by the company to the extent that significant losses are recorded in the acquisition contracts, they should be recognized in the financial statements together with the disclosure in the notes additional information on the circumstances that led to such an evolution.

The evidence regarding the disclosure of information in the financial statements is obtained through the substantive procedures described above. Further evidence can be obtained, as necessary, by consulting and reviewing the minutes of the board meetings and discussions with the company's management. On the basis of the evidence obtained and the comparison of the financial statements prepared with the requirements of the relevant presentation and publication standards, we have the possibility to determine the honesty of the presentation of the stocks in the financial statements.

## **6. Some suggested solutions**

Lately, the dependence between the need for information, the existence of a system to ensure their delivery and the development of society in general has become a reality.

The system that can provide the required information is the information system, for which the technique and differentiated means are used depending on the type of system to be built, the level of development of the company from the economic and informational point of view.

The development of computerized electronic systems has made it possible to replace traditional primary documents with technical information carriers that fulfill both the role of primary documents and those of technical data support necessary for their further processing.

Construction company's management should aim at implementing modern and up-to-date computer systems, namely choosing a multiuser database management system, meaning multiple users use the same remote database at the same time, resulting in a good use of resources server and memory savings, thanks to the unique database memory.

The facilities provided by the distributed databases provide the design of computer systems characterized by:

- the existence of a distributed database ensures the homogeneous grouping of all system data projected for shared use by all the functional compartments of the unit;
- ensuring an interaction between the creation and exploitation processes of the distributed database, allowing dynamic collaboration between its own applications and the link with other external systems;
- the availability of data in the current form required by the functional compartments and their operational transmission for the constitution of information support in decision-making.

## **7. Conclusion**

Improving inventory evidence leads to increased productivity growth, and the improvement of the information system is in fact the essential element for the transition to a new quality throughout the economic activity.

As a result of the study I consider that the main functions and characteristics that a manager has to follow for correct inventory evidence in a construction company are:

- inventory tracking at multiple levels: at unit / subunit level with own balance; at the management level, with the possibility of defining multi-level management hierarchies; in some cases management may choose to track physical location;
- transparent tracking of multiple inventory criteria: Different article codes need not be defined to track the same article entered into stock with different prices, the system solving transparently the management for each price; it is possible to track inventory with lots with distinct evidence on each, it is possible to track a serial number of stocks
- automatic cost calculation at management outputs: calculation method is selectable at management level (FIFO, LIFO, CMP set price with update after each move);
- real-time information and reports: stock lists at different levels, inventory balance, stock records;
- transfers between management, inventories and stock adjustments: transfers between administrations with automatic generation of appropriate operations according to predefined rules; in the transfer between administrations in two subunits, each with its own balance, the accounting records required in the records of each sub-unit are transparently generated; the system has inventory capabilities including sample inventory by the ABC method; pluses and gaps are controlled by documents, with the specification of the causes.

Following the study, I found that the inventory management system of construction companies should allow accurate inventory records by performing the following functions:

- the existence of a inventory of stock items;
- access by authorized persons to all necessary information. For example, the ability to set in real time the stock for an item in all the company's warehouses (headquarters, bases, units);
- all internal transfers are authorized only if they are in the budget. It is recommended that the degree of freedom from the budget should be at the recommendation / warning level and not at indicative / imperative level. Thus, if it does not fit into the budget, the system will allow for the transaction but will warn about overcoming budgetary provisions;
- the same initiation, approval and execution procedure for all sub-units on the same level;
- unitary, scientific, annual need determination;
- unitary, scientific, operative stock insurance procedure;
- unitary, scientific, periodical inventory management;
- the possibility of keeping records up to the storage position within the management;
- the possibility of requiring certain articles to be stored only in certain administrations or locations;
- the ability to restrict access to transactions only to authorized persons, by group of articles, for query / modification as appropriate;
- keep track of the history of the changes made to the inventory database, as well as of the persons who performed them;

- drafting stock value reports, by stock structures;
- the evolution of the stock structure over time based on framework contracts and the unit deliveries over the past 3-5 years;

Regarding the main objectives of stock management control at construction companies I believe that it should concern the following aspects:

- stocks are in good condition and are owned by the company;
- the costs of bringing inventories to the current condition and location were determined correctly;
- stocks were valued at the lower of cost and net realizable value, and adjustments were made to reflect the current state of inventories;
- all stocks are accounted for in the accounts;
- inventory valuation policies are adequately disclosed in the financial statements;
- the principle of independent exercises is respected;
- expenditures registered (materials, raw materials, labor, indirect costs etc.) are included in the production cost;
- the cost of production (materials, raw materials, labor, indirect costs, etc.) was correctly calculated;
- production costs were appropriately allocated,
- all the costs involved in production have been properly identified and recorded in the accounts;
- the cost of production affects the corresponding financial year.

## **References**

- Bătrâncea I., Dumbravă P., *Controlul si auditul financiar al entitatii economice*, Ed. Risoprint, Cluj Napoca, 2007;  
Brezeanu P., Braşoveanu I., *Audit financiar*, Ed. Cavallioti, Bucuresti, 2008;  
Dănescu T. , *Proceduri si tehnici de audit financiar*, Ed. Irecson, Bucuresti , 2007;  
Greuning H., *Standarde Internationale de Raportare Financiara*, Ed. Irecson, Bucuresti, 2009  
Lepădatu Gh., Jalbă L., *Audit şi control financiar*, Ed. Pro Universitaria, 2015;  
Matiş D., Pop. A., *Contabilitate financiară*, Ediția a treia, Ed. Casa Cărții de Știință, Cluj Napoca, 2010;  
Munteanu V., *Auditul intern la întreprinderi şi instituții publice*, Ed. Wolters Kluwer, 2010;  
Popa I., Man A., *Auditul financiar de la teorie la practica*, Ed. Risoprint, Cluj Napoca, 2009;  
Ravas B., *Control, audit si guvernanta*, Ed. Universitas, Petrosani, 2016;  
Voinea C.M., *Audit intern între teorie şi practică*, Ed. Pro Universitaria, 2016.  
*Legea contabilitatii nr. 82/1991 cu modificările ulterioare*  
*Ordinul Ministrului Finantelor Publice nr. 1802/2014*

# The Gender Gap in the Labour Market

Dorina Niță\*

*University of Petroșani, University street no. 20, Petroșani, 332006, România*

---

## Abstract

Nowadays we can speak about an intensification of concerns at national, European and global level relating to the presence of the female population in the labour market even though geographical, historical, economic and cultural contexts differ from one region to another, from one country to another.

The gender gap favours men, if we consider the rate of participation in the labour market, wage discrepancies or self-employment, or on the contrary, it is in the favour of women when we speak about atypical forms of employment (part-time work, or fixed-term contracts), precarious jobs, etc.; the gender gap is currently the subject of numerous studies and research that have the purpose of finding solutions for an efficient management of this phenomenon from the perspective of maximizing the benefits arising from the presence of women in the labour market.

*Keywords: labour market, gender gap, wage, employment, precarious jobs*

---

## 1. Peculiarities of female population in relation to the labour market

Discrimination against the female population, to varying degrees, is a real phenomenon that cannot be challenged, nor ignored, even though most Europeans consider that gender discrimination is no longer a problem nowadays, it was more predominant in “our parents or grandparents’ time”, than and anyway not as persistent as in the case of developing countries or Arab countries.

The reasons that lie behind such realities can be found in the patriarchal structure of societies, within the culture specific to various ethnic groups or peoples. With regard to participation in the labour market, the research report *The gender employment gap: Challenges and solutions* (2016), published by Eurofound identified, *in order to explain the persistent gender differences on the European labour markets*, the following determinant factors: individual characteristics (e.g. age, education, nationality and work experience), family and household circumstances (e.g. the presence of children and older relatives, civil status and unemployed partners), policy regimes and institutions (regarding the regulations on labour protection, tax and unemployment systems and or social policies relating to statutory maternity leave and child raising benefits), cultural attitudes and gender stereotypes (customs and stereotypes most often lead to segregation on the labour market meaning that men and women prevail in various fields of activity. Women can often be found working in health and social welfare, education, commerce as sales assistants or qualified and unqualified workers; these positions represent almost half of the female work force, with fewer representatives in administration and management). Moreover, it is considered that many of these factors overlap and are dependent on each other, which complicates the identification of key factors. The assimilation of modernity in different rhythms and ways for men and women, with its implications of expanding urbanization, the continuance of schooling or amplification of the participation of women in the labour market, has changed the mentalities and lifestyles among the female population. While men are reluctant to give up their dominant role, women much more easily let go of the humble and submissive attitude. At the same time, women have gradually exceeded their private space (which belonged to them exclusively and it still belongs to them to a large extent) getting into the public space (even though it is still dominated by men); this new situation has made women's lives more complex and even more difficult for this reason, raising a number of challenges relating to the reconciliation of family life with professional life.

---

\* Corresponding author. Tel.: +4.025.454.2581 int.200  
E-mail address: dorinamagda@yahoo.com

Currently, at the level of European Union countries, the legislative framework includes rules that relating to the prevention and punishment of discrimination, alongside with ensuring equal opportunities for men and women in the context of making the issues of equal opportunities the main part of the European Strategy for Employment. At international level, in most democratic countries, a number of conventions, declarations or treaties talk about gender equality in all areas of economic and social life. Any citizen living in a democratic country should have guaranteed fundamental rights, including gender equality, alongside the right to freedom of speech and opinion, the right to work and education.

## 2. Current situation of women's participation in the labour market

At present, the European Union labour market is facing a series of challenges and in order to deal with them it has to find realistic and effective solutions. Along with the aging workforce, discrimination and wage differentiation, predominant atypical forms of employment (part-time work, temporary work through an agency, etc.), the precariousness of jobs, chronic unemployment among young people, emigration, etc., one of the problems is the existence of a gender gap considered important between the participation of women and men in the labour market.

While the Lisbon Strategy established a target of 60% for women's employment rate in the EU which had to be reached until 2010, alongside the target of total employment rate of 70%, the Europe Strategy 2020 Growth Strategy for employment and smart, sustainable and inclusive growth, establishes the objective of achieving an employment rate of 75% for the population aged 20-64 years, without any set goal on gender equality.

Statistical data published by Eurostat shows that in almost all countries of the European Union the rates of participation of women in the labour market have registered an increase over the past decades, however their values continuing to be lower than those of men. At the same time, women's inactivity rates are much higher than those of men, mainly due to the inability of women to work because of their responsibilities towards the family.

In order to reveal the gender gaps between men and women in the labour market, a series of indicators can be taken into consideration:

- gender employment gap;
- unemployment rate, by sex;
- forms of employment;
- gender pay gap.

Gender employment gap is defined as the difference between the employment rates of men and women aged 20-64. The employment rate is calculated by dividing the number of persons aged 20 to 64 in employment by the total population of the same age group.

Women's employment rate shows the percentage of women out of the total of employees (men and women) aged between 20 and 64 years of age.

Data provided by Eurostat reveal an increase in the employment rates among women over the last few decades, however such an increase is due not only to the increase in the number of women employed, but also to the decline in the number of men employed. The employment rate among men registered groan increase between 2005-2008 at EU-28 level, losing 3.5% during the period between 2009 and 2013, however in the interval 2014-2017 slight trend towards recovery was recorded; the value reached in 2017 (78%) was slightly higher than the one recorded in 2008 (77.9%). The countries with the greatest drops in employment rates among men were Cyprus and Greece (more than 10%), followed by Spain (9.1%). During the same time period, the countries with the highest employment rates among women were Sweden, Germany, Lithuania, Estonia and Denmark, all with rates over 75%, while the EU rate was 66.5%. Greece recorded the lowest rate of employment among women of 48% at the level of the year 2017, followed by Italy (52.5%) [<http://ec.europa.eu>].

Table 1. Gender employment gap (%)

Country	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
UE-28	15,6	15,1	13,4	13,0	12,8	12,2	11,7	11,5	11,6	11,6	11,5
Malta	41,3	39,1	37,5	36,6	35,2	32,6	29,6	28,4	27,8	27,7	25,0
Italy	25,8	24,7	24,0	23,2	22,6	21,0	19,8	19,4	20,0	20,1	19,8
Greece	28,4	27,5	25,6	24,2	22,1	19,8	19,4	18,3	18,0	19,0	19,7
...											
Romania	13,1	14,3	14,4	16,6	15,3	16,1	16,3	16,7	17,5	17,6	17,1
...											
Latvia	10,2	7,4	0,3	-0,5	2,2	3,6	4,2	4,6	4,1	2,9	4,3
Finland	4,7	5,3	2,3	3,0	3,7	3,0	2,8	1,9	2,1	3,3	3,5
Lithuania	7,5	6,9	-0,4	-1,5	0,6	1,2	2,6	2,5	2,4	1,9	1,0

Source : EUROSTAT



The biggest differences between the values of the employment rates for men in relation to those of women, have been registered in Malta, Italy and Greece, between 19.7% and 25%, while in countries such as Latvia, Finland and Lithuania, the differences are less than 5%.

**Unemployment by sex.** If one analyses employment and the gender gap in employment, in parallel with the evolution of unemployment regarding both sexes, it can be observed that, with the exception of the years 2009 and 2010, when unemployment rates among men exceeded those of women, throughout the time interval 2008-2017 unemployment among women is higher than among men.

Table 2. Unemployment rate, by sex, in UE-28 (%)

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Males	6,6	6,6	9,0	9,7	9,6	10,4	10,8	10,1	9,3	8,4	7,4
Females	7,9	7,5	8,9	9,6	9,8	10,6	10,9	10,3	9,5	8,8	7,9
Gender gap	1,3	0,9	-0,1	-0,1	0,2	0,2	0,1	0,2	0,2	0,4	0,5

Source : EUROSTAT

As far as long-term unemployment rate by sex is concerned, it has reached almost similar values throughout the past years, being equal 4 years in a row between 2012 and 2015, whereas in the following years the values were higher in the case of women.

Table 3. Long-term unemployment rate, by sex, in UE-28 (%)

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Males	2,8	2,4	2,8	3,9	4,1	4,6	5,1	5,0	4,5	3,9	3,3
Females	3,3	2,7	3,0	3,7	4,0	4,6	5,1	5,0	4,5	4,0	3,5

Source : EUROSTAT

If one takes into consideration age when monitoring the evolution of the unemployment rate between men and women, data will show that the unemployment rate among young men (aged 15 to 24) is higher than the unemployment rate among young women.

Table 4. Youth unemployment rate, by sex, in UE-28 (%)

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Males	15,6	16,0	21,4	22,2	22,4	24,0	24,4	22,8	21,1	19,4	17,4
Females	16,2	15,9	20,3	21,4	21,8	23,3	23,8	22,2	20,3	18,7	16,8

Source : EUROSTAT

**Forms of employment.** When analysing the participation of women in the labour market it is not enough to consider just the quantity (the number of women employed, the number of unemployed women, respectively), but also the quality of their employment (by analysing the prevailing forms of employment). From this point of view, the participation of women when it comes to part-time jobs or temporary jobs is relatively high, and also when considering the sectors of economic activity with low pay rates, compared to men, a fact that significantly reduces their financial independence.

At the same time, women stand less chances of becoming entrepreneurs and better chances of becoming employees, as specialists explained due to the difficulties face by women in obtaining financing to start up or develop a business, to benefit from training or the need to reconcile professional life with family life.

Nowadays, another concern of specialists is related to atypical forms of employment, which have undergone significant development in the past few years (favoured by the outbreak of the global crisis); they are often associated with the so-called *precarious jobs*. As an alternative to standard employment contracts (for an indefinite period and full-time), fixed-term employment, part-time work, temporary work through an agent, sub-contracting, are forms of employment with a high risk of precariousness (due to job insecurity among the elderly, less protection of the employee in terms of social protection and pensions, etc.).

During the period 2008-2017, the employment rate of the population working part-time increased in all European Union countries, with significantly higher percentages among women. At the level of the year 2017, women who worked part time represented 31.7% compared to 8.8% in the case of men.

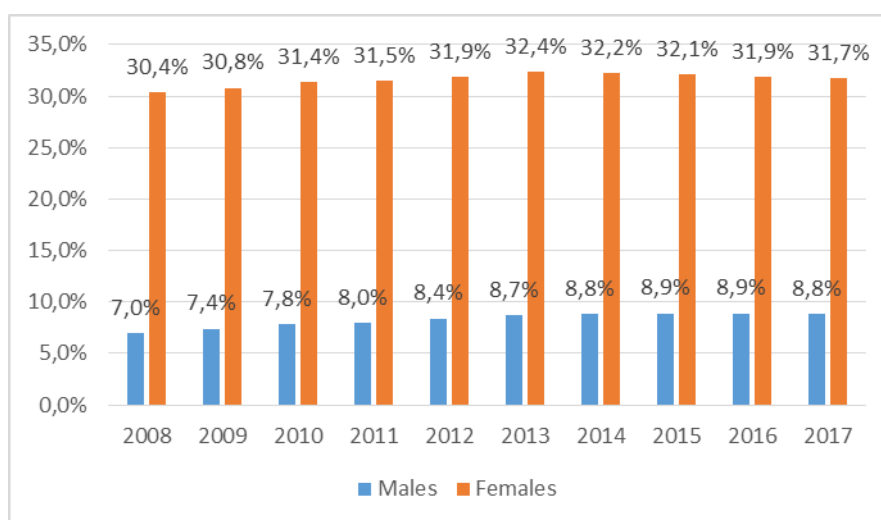


Chart 1. Part-time employment as percentage of the total employment, by sex

Source: <http://appsso.eurostat.ec.europa.eu/nui/submitViewTableAction.do>

As shown in the previous chart, the rate of part-time labour performed by women is about 30% for the analysed period, as it was the result of extremely different values recorded at the level of EU member countries. Thus, the Netherlands, which has the highest rate of participation of women in the labour market, also has the highest rate of part-time working women reaching almost 75.8% in 2017; followed by Austria, Belgium, Germany and the United Kingdom with rates ranging between 40% and 50%; at the same time, the proportion of women who work part-time was below 9% in Bulgaria, Croatia, Hungary, Romania and Slovakia. In comparison, men have recorded much lower rates to those women at the level of the same countries (in the Netherlands the percentage of men who worked work part time was 26%, whereas in the vast majority of other countries, the rates ranged between 2% and 10%). The gender gap was negative in all countries during the period 2008-2017, the differences being higher in countries such as the Netherlands (where it reached 51.5%), Germany, Austria and Belgium [data provided by Eurostat].

It is considered that temporary agency work (fixed-term) was the first way of managing problems in the labour market as a result of the global crisis. Thus, the restriction of the number of jobs in response to decreasing sales volumes and demand had been implemented by many companies, large and small, by not renewing the contracts of employment concluded for an indefinite period of time. If one analyses the evolution of the same indicator taking into account the share of women and men who provide services for a fixed period of time, then the data show higher rates for women in relation to men.

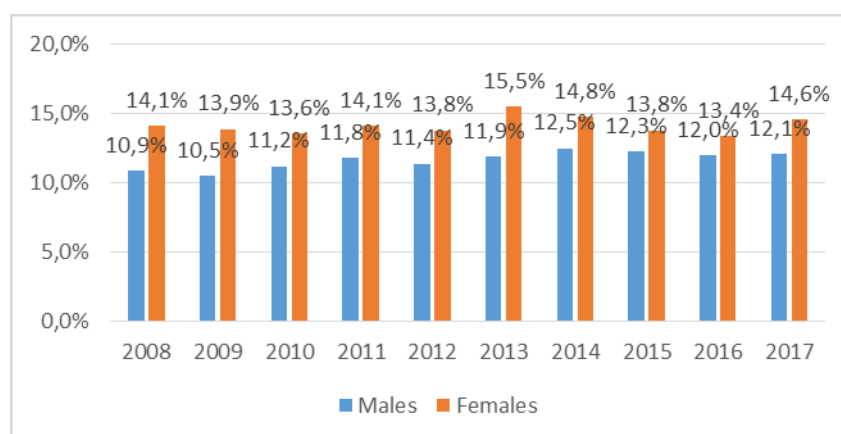


Fig. 2. Temporary employees as percentage of the total number of employees, by sex

After studying the development of fixed-term work at the level of the EU member countries, one can pick up on significant differences between their values. Thus, while the European average (EU-28) was approximately 13.3% in 2017, countries like Latvia, Lithuania and Romania registered much lower values (under 3%). At the same time, countries such as Cyprus, the Netherlands, Poland and Spain had the highest values related to temporary work among women (with values of over 20%) [data provided by Eurostat].

**Gender pay gap.** Despite the legislation aimed at fighting off wage discrepancies between men and women, there are still wage inequalities in all member countries of the European Union. The difference in remuneration between men and women represents the average difference between the pay rate of men and of women per economy as a whole. In Europe, women earn on average about 16% less than men and in some countries, the difference in remuneration between men and women is exacerbating.

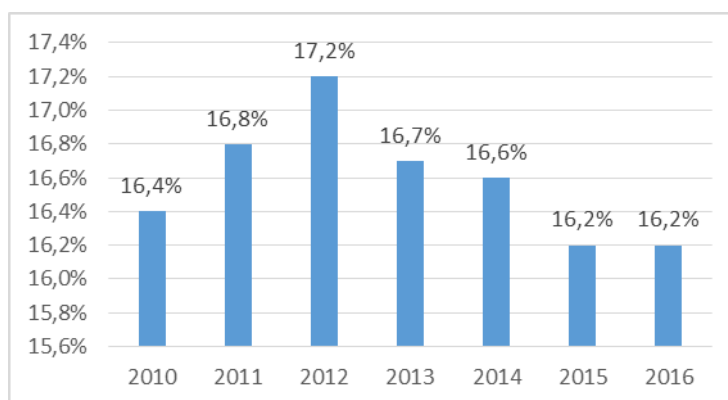


Fig. 3. Gender pay gap

Wage differences under 8% are registered in countries such as Belgium, Croatia, Italy, Luxembourg, Poland, Romania and Slovenia) while in the other five countries they exceed 20% (Austria, Estonia, Czech Republic, Germany and the United Kingdom).

The difference in remuneration between men and women has a significant impact on women's earnings throughout their life, as well as on their pensions. Lower pay rate means smaller pension and represents a higher risk of poverty for older women. The difference in pay between women and men is the consequence of continuous discrimination and inequalities on the labour market which, in practice, affect women in particular. This difference is relating to a number of elements both legal and of social or economic nature, which go far beyond the single issue of equal pay for the same work.

### 3. Economic costs of gender gap in the labour market

Of the disadvantages associated with the existence and maintenance of an important gender gap on the labour market we have listed the following:

- as women register lower levels of participation in the labour market this makes the national economy to be prejudiced by the additional income and a potential production;
- the lack of a job deprives women of welfare, thus the material security of the family can be affected if the husband does not bring in enough income;
- additional expenses incurred by the State with the assistance of this segment of the population (individual transfers of welfare and social benefits)
- the persistence of wage discrepancies between men and women for the same services provided makes women bear the consequences when they retire as pensions will be lower;

### 4. Conclusions

The purpose of this analysis is to highlight the importance of women in employment and to develop a perspective on how things could be different in the event that their participation would be higher; it is well known that reducing the gender gap in employment does not only lead to substantial monetary gains but also to social benefits (it is considered that the participation of women in the labour market improves the perception of the person in question on the quality of life in general and enhances the quality of the company. Women who work will assess life more positively than those outside the labour market. They enjoy a higher level of economic security, social inclusion and emancipation).

In all the countries of the European Union, there are gender inequalities even though with significant differences mainly on the labour market, where the employment rate of women is lower in comparison with that of men; women are to be found in larger numbers in lower paid sectors and they rarely in decision-making positions; the chances of becoming entrepreneurs are more reduced and the rate of pay differs too although they work the same jobs.

Despite the efforts of the institutions of the European Union and national legislation on the prevention and punishment of discrimination of women in the labour market and providing equal opportunities for women and men, progress is considered to be slow.

## References

- Isac C., Dura C., *Strategii investiționale în afaceri*, Ed. Universitas, Petroșani, (2008)
- Niță D., *Probleme contemporane ale ocupării forței de muncă*, Ed. SITECH, Craiova, (2013)
- Urse L., *Populația feminină: modernizare și adaptare*, Revista Calitatea vieții, XVIII, nr. 1–2, (2007), available online at: <http://www.revistacalitateavietii.ro/2007/CV-1-2-2007/9.pdf>
- \*\*\*, *The gender employment gap: Challenges and solutions*, EUROFOUND, (2016), available online at: <https://www.eurofound.europa.eu/nl/publications/report/2016/labour-market/the-gender-employment-gap-challenges-and-solutions>
- \*\*\*, *Raportul anual al Comisiei Europene privind egalitatea dintre femei și bărbați*, available online at: [www.eur-lex.ro](http://www.eur-lex.ro)
- \*\*\*, *Despre egalitate de gen*, available online at: <http://proiectul-elisa.fundatia.ro/despre-egalitate-de-gen>
- \*\*\*, *Egalitatea de gen – statistici la nivel European*, available online at: <http://www.femeiactive.ro/egalitatea-de-gen/>
- Institutul European pentru Egalitatea de Șanse între Femei și Bărbați (EIGE), available online at: [https://europa.eu/european-union/about-eu/agencies/eige\\_ro](https://europa.eu/european-union/about-eu/agencies/eige_ro)
- [www.ec.europa.eu](http://www.ec.europa.eu)
- <http://epp.eurostat.ec.europa.eu>
- <http://www.caleaeuropeana.ro/egalitatea-de-gen-in-ue-ce-arata-rapoartele-institutiilor-europene/>
- <http://appsso.eurostat.ec.europa.eu/nui/submitViewTableAction.do>

# Economic Value Added Relevance for Stakeholders Regarding the Quality of Performance Analysis of Romanian Metallurgical Companies

Elena Iuliana Ion<sup>a</sup>, Mariana Man<sup>b\*</sup>

<sup>a</sup>Craiova University, Faculty of Economics and Business Administration, Craiova, Romania, ion\_elena\_iuliana@yahoo.com

<sup>b</sup>Petroșani University, Faculty of Sciences, Petroșani, Romania, man\_mariana2006@yahoo.com

---

## Abstract

The effects of the economic crisis have had negative consequences on the economic sector that undergoes a vast process of improvement and continuous adaptation to the market requirements. In this context, companies are in a constant competition, looking for new levers to attract their customers and, implicitly, to increase their performance. Based on these considerations, this paper analyses the *Economic Value Added (EVA)* relevance for stakeholders measuring the performance of companies in the Romanian metallurgical sector, whose shares are listed on the Bucharest Stock Exchange (BSE). The theoretical and practical aspects presented regarding the EVA are points of support for achieving the objectives of the study and testing the two research assumptions: EVA determined depending on the global result provides a full picture on the global performance of the company; the company's level of performance is assessed similarly depending on EVA determined based on the global result, the total net profit and net profit in operation. The result of the research have been obtained through a careful study of the literature, as well as based on the quantitative analysis carried out in the case of a Romanian company in the sector of metallurgical industry. At the level of the company that was subject of the case study, EVA was determined and analysed depending on the global result, net profit from operation and the total net profit. It may be observed that EVA determined depending on the global result presents the company's global performance most accurately, which translates by creating value and achievement of profit.

"Keywords: Economic Value Added, performance, result."

---

## 1. Introduction

The sector of metallurgical industry is an indicator with a significant impact on the evolution of real economy in Romania. Taking into account that in the metallurgical sector, public investments are almost equal to zero and the foreign ones are decreasing from one year to another, we can affirm that metallurgical industry is going through a long period of crisis.

Under the conditions of economic growth registered in recent years, the Romanian metallurgical sector does not provide added value, being affected by the increase of the volume of imports. According to the statistics, in 2016, the turnover in the metallurgical industry has registered the lowest level in the last 4 years. Also, lowering the export demand, rising the prices of raw materials, as well as significantly lowering the public infrastructure projects are just a few of the reasons that have led to entry of many companies in this sector into insolvency.

The Romanian metallurgical industry is 100% privatised, being an extremely important branch for the national economy. This is why knowing the profitability rates expressed in relative size is even more important for stakeholders and, particularly for shareholders. They will want to know at any time the actual level of the company's performance, so that it can make long-term forecasts and prevent any financial imbalances. In this context, it is essential to know the factors that influence the performance of companies in the metallurgical sector, given that the Romanian industry faces a new challenging trend.

The analysis aimed at highlighting the EVA relevance in assessing the performance of national companies in the metallurgical industry, whose shares are traded on the Bucharest Stock Exchange. Based on the data taken from the

---

\* Corresponding author. Tel.: +40 764 34 94 33

ALRO S.A. annual financial statements related to the 2012-2016 period, we conducted an empirical study on the analysis, based on the EVA indicator. ALRO S.A. is a joint stock trading company, with a fully private capital operating in the field of metallurgical industry. The shares of the company are traded on the Bucharest Stock Exchange under the "ALR" symbol. ([www.alro.ro](http://www.alro.ro))

## **2. Reviewed Literature**

In the current economic context, taking into account the negative consequences of the economic crisis, globalisation is the main concern of business specialists and not only. We witness a process of adaptation and continuous improvement of information provided by the content of the annual financial statements under the conditions of increasingly more sophisticated needs of the accounting financial information users.

The company's profit obtained at the end of the financial year does not provide information on the created value to the holders of interests, but only shows the correlation between the company's incomes and expenses. Therefore, in order to know the shareholders' equity, specific tools to measure the managerial performances are required. Since maximising the value created by shareholders is the goal of any company, it is required to correlate the results obtained by the company at the end of the financial year with the shareholders' interests. The company's performance and culture indicators should aim at maximising the value created for the shareholders along with improving the company's financial statement. (Arnold, 2003)

Unlike the profitability rates reflecting the results generated by the activation at their historical value, EVA places a great deal of emphasis on maximising the value and on restating the components of the profit and loss account. EVA reflects the degree of a company's enrichment, after the company's investors' have been remunerated, or the profit acquired after deducting the cost of the invested capital. (Sichigea and Drăcea, 2006).

EVA is a modern indicator to measure the companies' performance, promoted by the Stern Steward consultancy office, which provides a higher level of company's profitability analysis compared to ROE (Return on Equity). (Sulger, 2008). This profitability indicator is of great interest especially for stakeholders, because it allows the assessment in absolute value of the equity in a company, respectively of the profit remained after decreasing the invested capital.

The main disadvantage of the EVA indicator is given by the influence the external factors have on its calculation, which shows a high degree of subjectivity in assessing this indicator. Given the current economic environment, characterised by a strong decline of predictability, the calculation of the EVA indicator is quite difficult to achieve because the method to calculate the cost of the capital invested has a significant influence on this indicator.

EVA tends to become a performance indicator of the company's management. According to EVA, the value can be created only if the investment brings to stakeholders a result better than their expectations. Therefore, a company can get profit when the value obtained is related to a profit better than the one it should get. EVA can be considered an indicator for measuring the internal performance of a company, calculated on the basis of the data observed. (Man and Vasile, 2009).

Because managers are responsible for the economic process performance and for the results of the main activities in operation, EVA should serve as evaluation and decision-making factor in the investment process. EVA reflects the company's performance in terms of the value created and not the profit. In order to create the economic value added, the profit earned after deducting the tax, it needs to be higher than the invested capital multiplied by the capital costs generated by the interests paid to the investors and incomes demanded by the shareholders. (Knapová, 2011)

At the level of companies and industries, EVA can be considered an ideal tool to compare the value created. A high value of the EVA indicator does not necessarily mean an increase in cash availability. Therefore, EVA cannot be considered an indicator for measuring the financial liquidity, as this refers only to the value created and not to the requirements regarding the company's liquidity. (Bharata and Alok, 2016)

According to Suwinto Johan (2018), at the level of the groups of companies, there is a connection between EVA and the return on equity (ROE) and the weighted average cost of capital (WACC) of the parent company. At the same time, this claims that a negative value of the Market Value Added (MVA) will generate an EVA negative value and, implicitly, a negative value of the difference between ROE and WACC.

## **3. Research Methodology**

In terms of the research methodology, the first step to carry out this study is to select the company that meets certain preset criteria. Among the criteria taken into account in selecting the company on which we have carried out a practical analysis, we list: the company has been active in the sector of metallurgical industry in Romania for at least 10 years, has shared traded on the BSE on 31.12.2016, drafts annual financial statements in compliance with the International Financial Reporting Standards, has an attractive and generous history for investors and, last but not least, it requires the easy access to financial and accounting information on the activity carried out. Thus, our case study will be conducted on the financial-accounting data reported by the ALRO S.A. company for the period of 2012-2016. The data required to carry out the study was collected by consulting official documents published by the company. The main objective of the research is to study the relevance of the result/profit when determining the EVA for the stakeholders who analyse the performance of companies in metallurgical industry.

This research has certain limitations, as it is specific to any scientific research. Thus, the main limitation of the research is the singular case of the company selected in the sample, as well as the limited time range subject to the research. Also, the lack of information regarding the managerial accounting and the substantiation of managerial decisions determine an incomplete formulation of future research directions.

**The assumptions of the research** carried out based on the analysis of the economic value added we want to test are:

**H1.** EVA determined depending on the global result provides a full image on the global performance of the company.

**H2.** The company's level of performance is assessed broadly depending on the EVA determined based on the global result, total net profit and net operating profit.

#### 4. Results and Discussions

The Economic Value Added (EVA) can be seen as expression of the profitability of the capital invested by the shareholders, following to determine that the difference between the net operating profit and the cost of the invested capital (invested capital \* weighted average cost of capital), according to the calculation equation (Jacque, 1997). Also, as can be seen in the Tabel no. 1, EVA can be determined as difference between total net profit/total result and cost of the invested capital.

Determining *the weighted average cost of capital (WACC)* assumes establishing the cost of the invested capital. (Venazi, 2012). This indicator reflects the level of profitability of the invested capital and is calculated based on the calculation formula presented in the Table no. 1.

The cost of the invested capital is determined by summing up the distributed dividends and the interest expenses. Thus, the relative level of the costs with the dividends and with the interest used in the financial resources of the company is determined by relating to the total value of the capital. The invested capital is that part of the total assets financed based on equities and long-term debts. *The invested capital (IC)* consists of the equity and the interest bearing debts. This indicator is determined according to the formula presented in the Table no. 1. (Peterspen and Plenborg, 2012)

Table no.1. EVA – calculation formulas

No.	Indicator	Calculation formula	Observations
1	Economic Value Added (EVA)	<b>NPO</b> $EVA = NPO - IC * WACC$	NPO - Net profit from operation
		<b>TP</b> $EVA = TP - IC * WACC$	TP - Total net profit
		<b>GR</b> $EVA = RG - IC * WACC$	GR - Global result
2	Invested capital (IC)	$IC = Eq + Ltd$	IC - Invested capital
			WACC - Weighted Average Cost of Capital
3	Weighted Average Cost of Capital (WACC)	$WACC = \frac{Cic}{IC}$	Eq - Eguity
			Ltd - Long-term debts
4	Net profit from operation (NPO)	$NPO = Si - Cgs - Gamc + Ooi - Ooe$	Cic - The cost of the invested capital
			Si - Sales income
5	Total net profit (TP)	$TP = Or - Ei +/- G/Lfin +/- OG/L +/- Nfed - Tp$	Cgs - The cost of the goods sale
			Gamc - General, administrativ and marketing costs
6	Global result (RG)	$RG = Rp + OENR$	Ooi - Other operating income
			Ooe - Other operating expenses
			Or - Operating result
			Ei - Expenses with the interests
			G/Lfin - Gains/losses from financial derivatives
			OG/L - Other net gains/losses
			Nfed - Net foreign exchange differences
			Tp - Tax on profit
			Rp - The result of the period
			OENR - Other elements of the net result, net of tax

Source: Processing based on the specialty literature

The literature emphasises the importance of a company's performance analysis based on the EVA indicator as the variation of the prices of company's shares is correlated with the evolution of the EVA indicator. (Bogeanu, 2013)

Even if using the EVA as indicator of analysis implies a high dose of subjectivity, we consider that the informational power of this indicator is quite high. In order to issue a personal opinion on the companies' performance analysis based on EVA, an empirical study was conducted in ALRO S.A., by using the financial data from 2012 to 2016. We chose to conduct the study in this company as this is representative in the sector of metallurgical sector, having the largest share of this market. In our analysis, EVA was determined as difference between the net profit from operation and the cost of the invested capital. EVA was also determined in the case of substituting the net profit from operation with the total net profit and the global result. Carrying out a comparative analysis of the results obtained resulted in issuing a personal opinion on the use of EVA as analysis indicator.

In Table no. 2, the EVA values are calculated for the period 2012-2016, in the ALRO S.A. company. EVA is determined depending on the net profit from operation, the total net profit and the global result. The values shown in Table no. 2 are expressed in thousands of Euros, at the exchange rate of the National Bank of Romania on 31.12.2017 (1 EURO = 4.6597 LEI).



The values recorded by EVA in the analysis time interval emphasise an ascending trend of the indicator, with the specification that only in 2016, EVA determined depending on the three factors registers positive values.

Table no. 2. Calculation of EVA for S.C. ALRO S.A.

No.	Indicator	2012	2013	2014	2015	2016
1	Net profit from operation (thousands of Euros)	-46,247	-45,210	6,826	33,764	36,399
2	Total net profit (thousands of Euros)	-19,745	-25,877	-23,321	-5,158	14,426
3	Global result (thousands of Euros)	-40,141	-26,620	-23,908	-4,015	14,337
4	Equities (thousands of Euros)	283,068	256,448	232,540	228,525	242,861
5	Total debts (thousands of Euros)	220,856	193,884	251,864	263,260	271,084
6	Invested capital (thousands of Euros)	503,924	450,332	484,404	491,784	513,945
7	Expenses with the interests (thousands of Euros)	10,428	11,851	11,489	11,479	13,279
8	Distributed dividends (thousands of Euros)	27,164	8	1	11,108	910
9	The cost of the equity (%)	2.05945275	0.00068245	0.00011889	1.0431266	0.08038758
10	The cost of the borrowed capital (%)	1.0133015	1.31173337	0.97895744	0.93579458	1.0512415
11	Weighted average cost of capital (%)	1.60096144	0.56514368	0.50906711	0.98566431	0.59246303
12	Cost of the invested capital (thousands of Euros)	37,593	11,859	11,490	22,587	14,189
13	<b>EVA (Net profit from operation) (1-12) (thousands of Euros)</b>	<b>-83,839</b>	<b>-57,069</b>	<b>-4,664</b>	<b>11,177</b>	<b>22,210</b>
14	<b>EVA (Total net profit) (2-12) (thousands of Euros)</b>	<b>-57,337</b>	<b>-37,735</b>	<b>-34,811</b>	<b>-27,746</b>	<b>237</b>
15	<b>EVA (Global result) (3-12) (thousands of Euros)</b>	<b>-77,734</b>	<b>-38,479</b>	<b>-35,398</b>	<b>-26,602</b>	<b>148</b>

Source: Processing based on the annual financial statements drafted by S.C. ALRO S.A., <http://www.alro.ro/ri/rapoarte-alro>

From the EVA calculations shown in Table no. 2, it may be observed that S.C. ALRO S.A. creates value for the shareholders only in 2016. The company has not created value for the shareholders in the time interval 2012-2015, EVA recording negative values.

One of the causes of registering some negative EVA values, between 2012 and 2015, would be the weighted cost of the capital that is too high for the company's shareholders. In order to increase the EVA, the company should pay particular attention to the evolution of the interests related to the borrowed loans as well as to the fluctuation of the course of the shares.

Following the calculations made and presented above at the level of ALRO S.A., **we emphasise the importance of EVA (calculated depending on the global result), on the assessment of the company's global performance expressed by the profit value during a financial year, as well as the by the value created for the shareholders.**

Using the EVA as tool for measuring the company's global performance brings benefits to the managers who will carry out the assessment of the efficiency of using the invested capital based on the profitability-risk relation. The main advantage of the EVA calculation depending on the global result is that company's managers will be oriented towards creating value and not towards getting profit. Thus, the interests of managers converge with those of shareholders, due to developing the levers that generate revenues higher than the cost of the invested capital, the ultimate goal of the managerial decisions being that of achieving economic value added, respectively profit.

Thus, by analysing the information shown in Table no. 2, it results that the **research hypothesis no. 1 is validated**, according to which *EVA determined depending on the global result provides a full image of the company's global performance.*

In terms of the EVA calculation depending on the net profit from operation, the total net profit and the global result between 2012 and 2016, it may be observed from Table no. 2 that these indicators register different values. In 2015, the assessment of EVA depending on the net profit from operation is a positive one as opposed to the assessment of EVA depending on the total net profit and the global result. Thus, in 2015, the company creates for shareholders an economic value added equal to 11,177 thousands of Euros taking into account the net profit of operation. If we relate to the net total profit or to the global result, in 2015, EVA will be equal to -27,746 thousands Euros, respectively -26,602 thousands of Euros.

In Table no. 2, one may observe the ascending evolution of the EVA indicator calculated depending on the net profit from operation, the total net profit, respectively depending on the global result, in the interval of 2012-2016. Although the evolution of the three indicators is approximately the same, the major difference is the significance of these indicators. In 2016, the EVA indicator registers positive values in the case of the three methods of calculation. These positive values of EVA show that the shareholders create value over the last year analysed. The reason would be a decrease of the weighted average cost of the capital, which determines an increase of the profitability of the invested capital.

It can also be observed that the negative values of EVA in the interval of 2012 – 2015 show the company's depreciation and destruction of the shareholders' value. In 2016, the company registers profit, after four years of consecutive losses. EVA obtained depending on the global result in the interval 2013 – 2016 registers approximately the same values as EVA calculated depending on the total net profit. The data in Table no. 2 are graphically transposed in Figure no. 1.

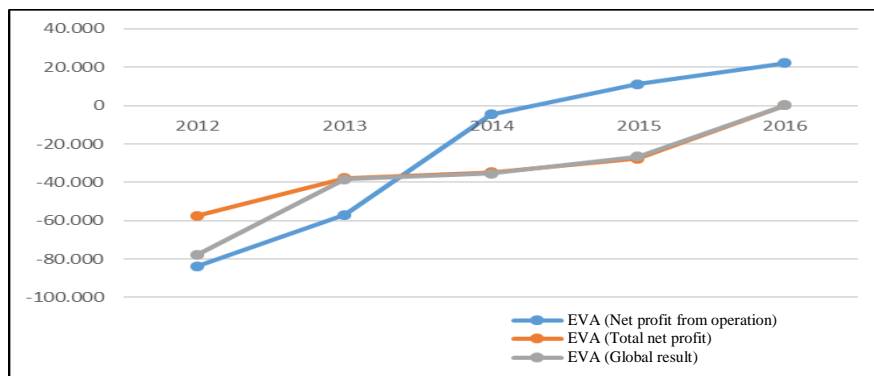


Figure no. 1. The EVA evolution calculated based on the net profit from operation, of total net profit and global result, for ALRO S.A.

Source: Processing based on the annual financial statements drafted by S.C. ALRO S.A., <http://www.alro.ro/ri/rapoarte-alro>

Figure no. 1 shows the ascending evolution of the three indicators and the value differences recorded by them. In the period of 2013-2016, EVA calculated based on the total net profit and based on the global result registers approximately equal values, with the specification that the global result provides information on the global value created for shareholders. Summarising, we may observe that the evolution of EVA determined depending on the global result is approximately similar to the evolution of EVA determined depending on the total net profit. Thus, the two indicators based on which EVA has been calculated provide comprehensive and appropriate information on the company's financial position. Also, from Figure no. 1, one may observe that EVA determined depending on the net profit from operation registers an ascending evolution in the analysed period, with the specification that the values of this indicator are higher between 2014 and 2016 and smaller in the interval between 2012 - 2013 compared to the values related to the EVA indicator determined depending on the total net profit and depending on the global result.

Based on the information shown in Figure no. 1, the **research hypothesis no. 2 is invalidated**, according to which *the level of company's performance is assessed similarly depending on the EVA determined based on the global result, total net profit and net profit from operation.*

## 5. Conclusions

Following the research carried out in the SC ALRO SA company, the influence of the EVA determined based on the net profit from operation, the net total profit and global result, over the level of assessment and company's performance. The results obtained following the processing of financial data reported by the company between 2012-2016 represented a real informational support on testing the research hypotheses formulated.

Thus, *the research hypothesis no. 1 has been validated* according to the results obtained. In this regard, we can state that EVA determined depending on the global result provides a full image on the global performance of the company. The interests of shareholders and of all users of financial-accounting information must be oriented towards a single purpose, respectively to create value and implicitly the acquirement of profit.

According to the information of the study conducted, *the research hypothesis no. 2 is invalidated*. Therefore, the level of company's performance is evaluated differently depending on the EVA determined based on the global result, total net profit and net profit from operation. EVA determined based on the global result provides information on the global value created for shareholders, while EVA determined based on the total net profit is the profit obtained by the company as a result of the economic activity carried out and EVA calculated based on the net profit from operation provides information on the company's profit from the operating activity.

In our opinion, a complex analysis of the indicators for assessing the company's performance should take into account a number of internal and external factors, as well as the increasingly more demanding of information users. We consider that EVA is a profitability indicator primarily oriented towards the value demand by the company as well as towards getting profit. Therefore, we appreciate that EVA provides a global image of the company's performance and brings more information to interested users. Taking into account the way to calculate the global result, **we consider that determining the EVA indicator based on the global result provides complex and realistic information on the value created to shareholders.** Thus, for a most faithful appreciation of the company's performance, we recommend the use of the EVA indicator calculated depending on the global result as it provides information on the **value of the profit obtained during a financial year, as well as the value created for shareholders.**

The main limit of the research is the limited sector for analysing the importance of EVA on assessing the company's performance. Therefore, future results shall take into account the expansion of the EVA analysis determined depending on the global result, total net profit and net profit from operation, at the level of several sectors of activity both nationally and internationally.

## References

- Arnold, G., *Corporate Financial Management*, Financial Times/Prentice Hall, London, 2.end edition, (2003).
- Bharata, B., S., Alok K., P., *Economic Value Added: A Better Technique for Performance Measurement*, International Journal of Advances in Management and Economics, Vol. 05, Issue 06, (2016), [on line] Available at: <<http://managementjournal.info/index.php/IJAME/article/view/61/61>> [Accessed 15 May, 2018].
- Bogeanu, A., *Correlations Between The Economic Value Added And The Price Of Shares*, Annals of the Constantin Brancusi University of Targu Jiu, Annals Economy Series, Volume 2, Issue 2/2013, pp. 115-122, [on line] Available at: <[http://www.utgjiu.ro/revista/ec/pdf/2013-02/18\\_Bogeanu%20Alexandru.pdf](http://www.utgjiu.ro/revista/ec/pdf/2013-02/18_Bogeanu%20Alexandru.pdf)> [Accessed 12 October, 2017].
- Dima, I.C., Man, M., *Modelling and Simulation in Management: Econometric Models Used in the Management of Organizations*, SPRINGER International Publishing Switzerland, (2015).
- Dima, I. C., *Systemic Approaches to Strategic Management*, IGI Global, USA, (2015).
- Jacque, D., *Rentabilité et valeur: MVA et EVA*. Analyse financière, no. 112, pp. 55-60, (1997), [on line] Available at: <<http://www.dominiquejeanjacquet.com/wp-content/uploads/2014/12/EVA-et-MVA.pdf>> [Accessed 07 October, 2017].
- Knapová, B., *Economic Value Added and Its Benefit for Owners and Managers of the Czech Compan*, European Financial and Accounting Journal, ISSN 1805-4846, Vol. 6, Iss. 3/2011, pp. 103-110, [on line] Available at: <<http://dx.doi.org/10.18267/j.efaj.28>> [Accessed 15 May 2018].
- Man, M., Vasile, E., *Economic Value Added - index of companies' internal performance*, Annals of the University of Petrosani- Economics, vol. IX, part II, pp. 115-120, (2009).
- Petersen, C., V., Plenborg, T., *Financial Statement Analysis. Valuation, Credit Analysis, Executive Compensation*, Financial Time Press, Anglia, pp. 107, (2012).
- Sichigea, N., Drăcea, I. E., *Sistem de indicatori de apreciere a creșterii de valoare a întreprinderii*, Revista Finanțe - Provocările viitorului, Anul V, Craiova, Nr. 5/2006, pp. 78-79.
- Sulger, R., M., *Valoarea economică adăugată. O cercetare empirică*, Revista OEconomica, issue 01, pp. 149-188, (2008).
- Suwinto, J., *The relationship between Economic Value Added, Market Value Added and Return on Cost of Capital in measuring corporate performance*, Jurnal Manajemen Bisnis Dan Kewirausahaan, Volume 03, No.1, pp. 23-35, (2018), [on line] Available at: <<https://journal.untar.ac.id/index.php/jmbk/article/view/1293/826>> [Accessed 15 May 2018].
- Venazi, D., *Financial Performance Measures and Value Creation: The State of the Art*, Editura Springer, Rome, pp. 24, Available at:<[http://www.alro.ro/sites/default/files/alro/2017/Raport%20anual%202016\\_Alro\\_RO.pdf](http://www.alro.ro/sites/default/files/alro/2017/Raport%20anual%202016_Alro_RO.pdf)>, (2012), [Accessed 05 October 2017].
- <http://www.alro.ro/ri/rapoarte-alro>.

## Bitcoin - the economic unit of humanity?

Cosmin Rus<sup>a\*</sup>, Ileana - Sorina Rakos<sup>a</sup>

<sup>a</sup>University of Petroșani, Street Universității, no.20, Petroșani, România

---

### Abstract

This paper highlights aspects of the Bitcoin digital paradigm that use decentralized technology for secure payments and the storage of money that does not require banks or names of people and which occurred in the context of the economic and financial crisis of 2008. The main objective of the chapter is the understanding of the dilemma synthesized in the question: Is the bitcoin a currency of the future, of technological innovations?

From the user's point of view, Bitcoin is a mobile application, a computer program that provides a Bitcoin personal wallet that allows the user to send and receive bitcoin messages representing the purchase or sale of goods and services. The massive public register called the "blockchain" used by the Bitcoin network is comparable to what was twenty years ago for the public finance world. The Internet for the Information World: a technology that allows fast, secure and decentralized transactions. This leads us to believe that over the next 50 years, more and more people will enter this network using electronic money as a means of payment. The fact that today renowned companies use this exchange rate also causes us to believe in its power and ultimately its acceptance as a means of payment. What is interesting about this digital coin is that much of Bitcoin's trust comes from the fact that it does not require any confidence. Bitcoin is fully open and decentralized. This means that anyone can access the entire source code at any time. Any developer in the world can accurately check the way Bitcoin works. All transactions and bit marks issued in existence can be viewed in a transparent, real-time manner by anyone. All payments can be made without relying on a third party, and the entire system is protected by peer-review cryptographic algorithms, such as those used for on-line banking. No organization or person can control Bitcoin, and the network remains secure even though not all users can be trusted. The issue here is whether it will replace today's physical money and whether it will have a central regulator over the course of time, as Bitcoin has become a very popular currency in recent years, being the most widely used global ban. What seems impossible now can be widely used in the future. The issues presented by the authors are based on the literature that has existed so far in the world. Through the authors' contribution, the conceptual framework of the emergence and use of this exchange coin is disseminated, leaving time to say its word on all aspects of creating and using it.

**Keywords:** bitcoin; stock market; financial market; payments; currency; risk

---

### 1. Introduction

With the progress of mankind, the need to move goods acquired through specific activities began to increase. In the prehistoric age, when people were carrying a nomadic way of life, hunting and collecting supplies to support their tribes, there was no need for exchange, because once the supplies were completed on a certain territory, the group moved to other unused territories. But with the transition to the sedentary way of life, the Natural Economy emerged, given that in the newly formed localities the social-economic network was not so well developed, so people produced by the processing of the earth, hunted and picked, the whole spectrum of goods needed for survival, basically not demanding exchange (the exchange was rare and in the form of a barter). Over time, due to social development, this type of economy has become ineffective because households have failed to self-supply because of the increase in population, economic specializations such as metal processing (especially in cities) have emerged, so the need for a standard to serve as an intermediary, the ban being virtually eliminated, that is, an economic standard, with which the value of a good can be measured, and, if that standard is in possession, the purchase. So the concept of money appeared.

At first, a lot of materials circulated in the form of money: from pearls and spices in Oceania and India to animals and fur in Euro-Asiatic areas. Over time, the role of money has begun to fulfil its metallic materials, thanks to the appreciation of skilled metalworkers. For this reason, the role of money was at the top of arrows, targets, nails, etc. Due to the efficiency (for that era) of this mode of payment, the metal was used in its entirety: copper, bronze, iron, silver. The more rare the metal, the higher its price, the gold is the most valuable. In some states, such as Assyria and Egypt,

---

\*Prof. assist.dr. Rus Cosmin, University of Petroșani, e-mail: CosminRus@upet.ro

gold was used as gold, even 2000 years before our era. But the metal circulation in the economy brought inconveniences, since there were no coins, the metal was transported in large pieces. For any exchange activity, the metal had to be weighed and checked its purity (sample). To avoid scams, the metals began to be marked with public seals, so coins and coins appeared.

During the use of the coins, there was a tendency to wear out and the inconvenience of keeping it, because the metal was difficult to transport and vulnerable to theft. So money retention organizations appeared: The First Banks. They were working on the following principle: a person puts his money in storage, the bank offers him a certificate confirming that his fortune is at the banker, and once the person presents that certificate (receipt) to the bank, he can withdraw the amount of money deposited. Thus, to pay a bulk purchase, people could only offer the certificate instead of a large amount of coins. Over time, these certificates began to have the same economic power as real money. Thus, the first form of paper money came from: the practice of using bank certificates for buying a good. The very term banknote originates from the English bank note meaning "bank certificate". The bank's economic goal is the bank's commitment to freeing real money. Today, however, this concept is out of date, with the banknotes already fulfilling the real money function.

## **2. Bitcoin, between scam and revolution**

In 2009, due to the increasing popularity of electronic payment systems, a person or a group of unknown people, under the pseudonym Satoshi Nakamoto, created Bitcoin. It can be defined as a decentralized electronic payment system, but also a digital coin. The purpose of this coin is to ensure security and transaction anonymity, free business finance, and investment protection without resorting to public or private financial institutions, thus excluding dependence on a certain financial structure. As we know, the world currencies have a special issuer: The dollar is issued by the US Federal Reserve System, the Euro is issued by the Central Bank of Europe, etc. Unlike these coins, Bitcoin does not use a central issuer, being totally decentralized. Economically speaking, Bitcoin has no value, and is used as a measure of the value of traded items, basically fulfilling the original money function. Bitcoin's value is based on the confidence of all participants in this coin's trading network.

Next we will address the technical aspect of this coin, because without it, we cannot understand its principle of operation. It's a bit heavy, but we'll try to make it as suggestive as possible. Due to its construction, the Bitcoin can be anonymously transmitted, and saved on the user's computer as a portfile. In order to make a transaction, users need two "keys", a public one, which is used to encrypt the transaction code and BitTorrent, and a private one, with which the code is decoded, and finalizing the transaction, offering anonymity and security.

Another feature of bitcoin is transparency: any Bitcoin user can see all transactions made by all network users in real time. Anonymity in this context is that we only see transactions between wallets, not who owns those wallets, we basically see just how money is handled. This is possible thanks to Blockchain, which is nothing more than the register where all transactions are entered, and which helps to achieve the transparency mentioned above.

The end point of transactions is public keys or addresses. Any user can generate an unlimited number of addresses, which increases security and anonymity. Transactions on Bitcoin are based on the following principle: When a user transfers an amount to user B, A drops the property on the BitTorrents sent by adding the user's public key B and signing it with their own private key. It spreads these bitcoins with an appropriate message, the transaction, into the bitcoin network. The rest of the network nodes validate the cryptographic signatures and transaction amounts before accepting it.

In our opinion, the concept of crypto-labelled is perspective, but Bitcoin does not have a high practical capacity, because of how paradoxically it would be, its main plus: decentralization. Because of this facility, this currency cannot be controlled by the state, it does not depend on any bank, it cannot suffer inflation (the number of bitches being controlled), what is the problem then? The problem is the financial value of a Bitcoin coin. The course of this cryptovate is very unstable, sensitive to crises in economic life and investor actions. Let's do a little analysis: In the year of its creation: 2009, a Bitcoin could be bought with \$ 0.30, but by 2012, over three years, its value has risen to \$ 14. So, if I was investing a small amount of money in Bitcoin, over three years I would have done 46 times more. This increased the number of miners hoping for a slight gain. If this course change looks strange, the next one seems fantastic: in 2013, a Bitcoin's price explodes from \$ 14 to \$ 1,000, that is, it's 71 times higher. This was due to the economic crisis in Cirrus, which led to the blocking of depositors' accounts in several banks, and investment in infrastructure for Wall Street investors. These events have influenced entire companies to go through a professional mining process, buying a lot of computers for this purpose, and more and more people have started investing in this currency with the hope of further growth.

But in many countries Bitcoin was banned, China being the most representative. For this reason Bitcoin's price has fallen from \$ 1000 to \$ 400. Following the multitude of fluctuations, ups and downs, Bitcoin reaches its historic record in 2017: \$ 16,500 could be bought with only one Bitcoin coin. It should be noted that, like the physical currency value distribution (one dollar is equal to one hundred cents), the Bitcoin has its subdivisions, so analogically to Bithoin in the Bitcoin system is Bitcent, which uses 0.01 bitcoins. The smallest subdivision is considered Satoshi worth 0.0000000001 bitcoins. At the time of drafting this work, the bitcoin rate was \$ 7300 per unit. We have avoided the expression "at the

moment" because of the instability of this cryptoplane, because the price of this coin cannot be said with certainty at the moment of rereading the work.

For this reason, we consider Bitcoin as an ordinary user of economic facilities not to give me great advantages because, suppose: in a supermarket we paid a sum of 100 ron in Bitcoin. In a while, if Bitcoin drops, I'll make a profit because I've lost a bit of Bitcoin that has now devalued more, but if the Bitcoin course grows, it turns out we lost much more than if I paid in ron. It follows that no matter how innovative and perspective the Bitcoin idea would show, the fact that they cannot apply it in practice stops me from everyday use of this coin. In addition, there are arguments that claim that Bitcoin is just an experiment, or a Pyramidal Game designed to enrich those who speculate the market behavior of this coin. The biggest scandal in the history of this coin was the theft of 120,000 bitcoins, which destroyed the myth of the safety of this cryptobucket.

### **3. Blockchain and cryptocurrency**

We have to understand that creating cryptolane is not the only single use of Blockchain. In 2015, the Ethereum network was launched that generated far more modern technologies than Blockchain and other concepts such as smart-contracts. Ethereum was a Blockchain, but more technically advanced not only to perform currency transactions but also to initiate and process smart-contracts, create its own Token devices (identifies you as a user and authorizes your transactions) for use in any other (third) projects.

Smart-Contracts is a new direction, which became known with the development of the Blockchain. Imagine a smart electronic contract that records all business conditions and cannot be changed by anyone. This technology will generate the complete disappearance of scams and lies, both from simple people and from the state. For example, you have created a smart contract for the sale of a good (your own house), you have scheduled the necessary conditions after which the smart-contract will create the necessary events (in our case the sale of the house (sale of the private-real estate)). Therefore, the buyer transfers the necessary amount of money to the smart-contract to the corresponding smart-contract, after which the smart-contract verifies daily the update in the State Property Register. As soon as the property registration letter is displayed after the new owner, the smart-contract will transfer to your account the amount equal to the price. If within one month this inscript will not be displayed, the smart-contract will return the buyer's crypt. This is one of the simplest examples that make it clear that in front of Blockchain technology there is a big future. Blockchain and cryptocurrency are now like the Internet in 1993, everything that's more interesting is going to happen. And it is very important that we all understand this new direction, and if we have the opportunity, let us even take part in it.

The analysis of the theories that refer to the two largest and most crippled in terms of capitalization shows us the following: Bitcoin - \$ 290 billion and RIPPLE - \$ 120 billion, data recorded on January 6, 2018. The total capitalization of all crypto- today is about \$ 800 billion, just one month ago, rising to \$ 450 billion. And these are small drops in the sea, because, according to analysts, by 2022 the total capitalization will grow to 20-30 trillion dollars, an enormous market and an ultrafast growth.

Blockchain is a total decentralization, no intruder has access and the ability to introduce changes in information and transactions. Decentralization is accomplished by distributing servers that store and process information. The more servers are left each other and the less the server owners are linked to each other, the deeper the decentralization system is.

### **4. The hazards associated with bitcoin**

Until now, we only talked about how positive and efficient the cryptocurrency and the Blockchain technology system is. But you probably wonder why the paper is called "Bitcoin - the Economic Assassin of Humankind." What we have exhibited so far provides us with a basis for understanding the second part of the paper, which actually makes reference to its title. Next we will address the danger and risks associated with Bitcoin and RIPPLE.

Not in vain we have called the work, the bitcoin is wonderful, the technology through which it is created is even more beautiful, and what is happening now is totally the merit of the bitcoin, but we must understand that bitcoin is not just a simple technology, it accumulates enormous amounts of money, it has practically become digital gold, as many people call it. Before people bought gold, and gold itself served to beat certain coins of different states, but that is already history. For a long time, no country has guaranteed its national currency by covering its gold reserves. This phenomenon has transformed the issue of the world's most important currency, the dollar, into an endless process. US Federal Reserve Printing Machines are printing dollar-type banknotes infinitely and unrestrictedly in order to have enough American food supply. Thus, new figures will appear in the accounts of banks, which will later turn into credits for companies and simple people. This phased process then causes inflation. You will never be able to raise enough dollars because they devalue over time. You'll just have to get credits when you want to buy something, because the "entire" amount you need will never be enough. This is how the world monetary system works. This problem has begun to battle the bitcoin and other cryptoplane. If the total bitcoin capitalization is currently \$ 290 billion, digital extraction can be obtained or extracted around 16-17 million dollars coins-bitcoin, and in 2140, for example, it will be possible to extract 21 million coins.

If Bitcoin now costs \$ 17,000, it does not mean you can buy Bitcoin from at least one currency. This moment was thought from the start. Thus, a bitcoin is divided into several parts, called "Satoshi". The minimum bithole is equal to one millionth Satoshi, assuming it would cost \$ 100 (suppose, because the cost will change permanently, because the currency is constantly rising). That is, any of us can buy a part of a Bitcoin coin if it has the equivalent of the cost of that million Bitcoin. Finally, we have a currency that is not controlled by anyone and whose cost increases. On January 6, 2018, a coin worth \$ 17,000, and according to analyst data, in 2022 a Bitcoin's price will reach \$ 100-200,000, when everything started when Bitcoin was worth less than 1 cent. As soon as Bitcoin moves to a certain psychological threshold, his price worsens to a new rise, as it has come to worth a thousand dollars, ten thousand, and so on. No one can stop transactions in the Bitcoin network and other encrypted ones, no one has access to data on your accounts, block them, or do anything else. This particularity of Bitcoin we consider, as is normal, welcome and positive.

As we know, the creator of Bitcoin is a person, or a group of people, known under the pseudonym Satoshi Nakamoto, who first launched the Bitcoin network. For testing and verification, around 7% of all Bitcoin coins were extracted, and today, in a few years, those 7% represent colossal amounts, approximately \$ 20 billion, and after forecasts only 7% will almost equal \$ 200 billion, and by 2050, these percentages will turn to \$ 5-10 trillion. And it is very possible that at that moment to be the opposite of the present, ie the value of the dollar to be calculated in bitcoins, even if that sounds funny, this is likely to happen. So funny sounded for that boy who bought a 10,000 Bitcoin pizza in 2010, hearing that in 2018 the equivalent of that price would be \$ 150 million. Ask a financial analyst or economist who you know about the danger of this phenomenon. What will happen if 7% of all Bitcoins are extracted in a single day at cryptocurrency exchanges?

We will see how soon Bitcoin, but also the other cryptocurrency, will be destroyed. Their value will decrease hundreds of times, creating such a catastrophe in the world that most financial organizations, traders and others will have to stop trading and sales. In fact, the entire world economy will stop in just two or three days. Stores, pharmacies, no trader will be able to accept payments, because everyone, a day ago, bought goods at a price hundreds of times higher. Everyone will wait for clarifications, which they will not receive. There will be such a crisis and waves of robberies as they have never met. People will have nothing to do but get the necessary burglary. This situation will use the poor class of society, and under the tide of robberies will hit not only the shops and pharmacies but everything that will appear in their path. It is possible that the states of siege and everything we have seen in the films about the future will happen. And the probability of this situation is very high.

Imagine that in your house there is a room that is full up to the bridge with \$ 100 banknotes, so if you want to open the door, you will be covered with waves of money. And you have been living in that 9-year-old house, and in all these 9 years you've passed that room without taking even \$ 1. Tell me, would a simple man be capable of this? I do not think anyone would have this strength.

That would be the main feature of Satoshi Nakamoto, if it were one man. But we understand that this is not possible. Whoever would have used this enormous fortune. But since 2009 no transaction has been made from Satoshi's accounts, no Bitcoin has been spent, except for a small portion that was spent on testing at the beginning. This initiator, either a person or a group of people, unites them with an extraordinary purpose for which they are ready to reject billions of dollars and wait even more than 10 years. It all resembles a Hollywoodian movie where a team of programmers creates a new digital or virtual financial network, waiting for a moment to squander the entire economic system, generating waves of looting and chaos in which the world will shake and it will transform into something, something unimaginable. But the goals of this anonymous group are of serious concern, and we must understand this and strive to prevent this variant of the future. How do we do that? Everything is simple.

We must not allow a sudden rise in the cost of the Bitcoin, and its capitalization, until it is understood who Satoshi Nakamoto is. If he is an ordinary man, then he will have to transfer an overwhelming part of his Bitcoins to an account (his own account, in which to secure some of his wealth) from which it will not be possible to carry out the transactions future. Simply put, he has to destroy some of Bitcoin's sum of his. In this case, it will eliminate the danger of such events that we have previously talked about. But it is unlikely that Satoshi Nakamoto will appear, and he will not do that, since he waited nine years without touching his or their wealth. Each of us tends to hope that Bitcoin will destroy the current financial system in which 50% of all the riches of the world are concentrated in the hands of a small percentage of the population, but we now see that 40% of all Bitcoins have only a few thousands of people. Then what is the difference between digital gold and the current financial system? It's nothing. This is also an unfair distribution, even more unfair than the present one. Bitcoin Blockchain, however, has an algorithm that allows you to introduce changes in transactions, changing transaction history, account balances, and other actions by someone else outside of you. How is that possible? Simple, if someone controls 51% of the Bitcoin network servers. You will say that it is not possible, because earlier we said that these are the advantages of Bitcoin and Blockchain. But everything is different. When Bitcoin was born, its existence and maintenance needed to create a network of volunteer servers that had to be rewarded for using their computers. That's how the mining appeared. The mining was first introduced into the Bitcoin algorithm and thought out in detail until the year 2140, where with some passages of time, mining becomes more and more difficult. From the very beginning, the Bitcoin network was composed of enthusiasts who offered their computers virtually free of charge, when Bitcoin was worth less than a cent. But then, with Bitcoin's price rise, professional miners began to appear, after which mining pools appeared, where powerful miners joined, mining equipment manufacturers emerged and created a capable system to resolve Bitcoin's requirements much faster than any other regular computer,



how powerful it was. Bitcoin attempts on ordinary computers have completely disappeared. Mining is a very wasteful electricity process, for the location of large mining devices, very cheap electricity access is needed, as is a favorable climate area. Mining equipment produces a large amount of heat that needs to be absorbed. After these clues, in your opinion, in which country are the capabilities and basic tools that Bitcoin is shuffling for? This is China. In the percentage ratio, it looks like this: China 81%; Japonia5%; Czech Republic 2%; Georgia1% etc. If most of Bitcoin's power is in a single country, it allows for a simpler connection between mining equipment owners, which causes danger. It is enough that these owners, uniting themselves, form 51% of the administrative equipment to make changes to the Bitcoin network. Mining pools already have their own brands and names, they have long known each other, and possibly keep in touch with each other.

When the Bitcoin network was designed, it probably did not think of such an unfolding of events. According to the initial ideas, the Bitcoin network was to be distributed all over the world between the small, separate and independent miners, but everything went different. Mining is an enormous process that has long gone beyond millions of dollars. Today's modern cryptodoletes are no longer in need of mining. More secure and cheaper Blockchain projects have been designed and are already in place, where the role of mining is diminished, not much electricity is needed (Bitcoin currently consumes energy as a city with a population of 1 million people). Here too we can add accelerated demodulation of mining equipment, it will be an endless race. The equipment purchased yesterday, tomorrow, may be old and out of date with the release of new ones.

I reviewed and analyzed the most important hazards that Bitcoin might pose. But what to do to avoid all this? Everything is simple and complicated at the same time. Cryptocurrency's company must not change Bitcoin's price higher than it has at present. Most believe that \$ 50-60 thousand is a reasonable limit for the Bitcoin value and safe for the cryptocurrency market, because if someone tries to destroy Bitcoin, the rest of the cryptocurrency will fall. We need to assess the situation correctly and not lift the Bitcoin up to those heights that may prove dangerous. We, society, can create a more positive future in this respect, which we will continue to talk about.

## **5. RIPPLE and ICO**

We can think that only Bitcoin can create danger, but it is not. There is also the Altcoin, which, like Bitcoin, does not have to get big bucks in its capitalization. RIPPLE is also a digital coin and a company that connects global banks and cross-border payment processors. But what's wrong with this cryptocurrency?

RIPPLE is created by bankers for bankers, and most importantly, it is not even Blockchain, but a centralized network. This is the most interesting case. How could such a project get into the cryptocurrency society ... So if the network is not decentralized then all the management tools, all the assets and functions belong entirely to the owners and founders. An even more scary factor is that of all the monetary units issued, only 40% is available for transactions on Crypto-markets (online currency exchange service). Thus, it is noticed that the largest quantity - 60% stands, or is owned by the project owners. We can attribute this to the term cryptomonetic balloon. The second frightening factor is the newcomers to the crypto-loop society, who do not yet know how to distinguish the true crypt-dubbed projects like RIPPLE. Because of this, it responds with enthusiasm to any outburst of information that raises the RIPPLE capitalization to the sky. Right now RIPPLE takes second place after capitalization, yielding only to Bitcoin. 120 billion versus \$ 290 billion, is a very alarming trend, with great chances that RIPPLE will soon become a leader. But let's hope that common sense will triumph, and these projects will not rise up as this "cryptomonetic balloon" can be created specifically so that when the banks will need to ruin the world of cryptocurrency.

We have all heard of big gains by investing in cryptocurrency, but beginners notice that investments in top-rated cryptocurrency that reach peak heights do not yet bring as high profits as they would have desired. Blockchain technology needs development. There are many projects that work to develop Blockchain technology to implement it in real life. The cryptocurrency world is looking forward to the moment when Blockchain will start to be used in daily society and this trend is facilitated by ICO (Initial coin offering). This is a new concept that has recently appeared. One of the largest ISO has become Ethereum, which we talked about earlier. The team and founding organization needs financial resources to create and implement ideas within the realm, mainly related to the Blockchain and cryptocurrency network. ICO is the first stage when the currencies of a new forward-looking project can be bought at their minimum value, after which the project collects a sum determined from individual sponsors and investment funds, then project processing and ICO coins start appearing on cryptographic markets. Subsequently, depending on the project, the cost of the coins increases. The most striking growth after the ICO was the Stratis coins, which grew by 151,000 per year only in one year. That is, if you had invested \$ 1,000 in the Stratis coins when you were in the ICO, then in just one year your investment would have brought you \$ 1.5 million. But there are risks too, because these stunning successes are used by the scammers, initiating impossible projects, only to cause damage to society. So, think well what you decided to invest in.

Since this year, more and more projects are being called for to unite real life with Blockchain technology. For example, the ICMP ARMPACK project to be launched this year. ARMPACK aims to escape the world of speculation and fake goods through Blockchain and provide a useful mobile application for anyone to pay for the purchase of cryptoduites, keep different cryptovates, check the originality, the origin of the product, the manufacturer's contact details, get discounts, participate in different actions, and the manufacturer pay you with Bitcoin for shopping.

ARMPACK manufactures logistic servers in Blockchain which represent more advanced marketing opportunities for customer communication. The use of the ARMPACK network by any company will allow the technology to penetrate into all Business processes. All processes are united and interdependent in a single Blockchain ecosystem, taking place in smart-contracts that offer 100% security against fraud. Unfortunately, such projects appear rather rare, but we notice that the market is being corrected over time and there is a great future ahead of Blockchain technology. No cryptopod must have a huge domination. The list of 150 cryptovalents must be constantly capitalized. There must be no encryption of 10 to 20 or 30 percent of the total capitalization of all cryptovalents. But if this happens, the same dollar will be earned, and again, an inequality between people if there is something unique in the world. There must be no such thing. All members of the crypto-loop society must understand that the market will be safer and steadily growing when there is not a strong dominant danger.

## 6. Conclusions

We have approached Bitcoin from the multitude of cryptovudes on the market because of its popularity, being the most used electronic money. From the ideas outlined above we can deduce that Bitcoin has no practical value, but it is not. Even if bitcoin use is somewhat more difficult because of its volatile course, the popularization of this coin has led to the development of cryptoplane itself, which is economically important. More stable and more practical cryptoscopes appear: Ethereum, Litecoin, Yota, which, over time, may replace the concept of paper money, and move to electronic money. Technologies are growing at an accelerated rate, and financial security is getting bigger every day, so implementation of cryptobodies might be an action that would provide economic prosperity in the future, yet they eventually meet the concept of money base: measuring the value of a product, and facilitating the exchange, that is money is a tool with which the exchange becomes effective. Money presents our economic capacity, and cryptovalata is a concept that attempts to implement this money feature in reality. As mentioned earlier, once and spices were considered "gold", which means that the nature of money is flexible, and what seems impossible now can be widely used in the future.

## References

- Antonopoulos, M., *Mastering Bitcoin: Unlocking Digital Crypto-Currencies*. O'Reilly Media, (2014)
- Davis, Joshua, *"The Crypto-Currency: Bitcoin and its mysterious inventor"*, The New Yorker, (2011).
- Detrixhe, John, *"The secret to crypto investing is there is no secret"*, 2018
- However, Goldman reports that Google wanted to create something similar to Bitcoin, but decided against it for regulatory reasons (2012).
- Jason Mick *"Cracking the Bitcoin: Digging Into a \$131M USD Virtual Currency"*. Daily Tech, 12 June (2011).
- Lee, Timothy B. *"An Illustrated History Of Bitcoin Crashe"*, (2013)
- Nakamoto, Satoshi, *"Bitcoin"*, (2009).
- Nakamoto, Satoshi, *"Bitcoin: A Peer-to-Peer Electronic Cash System"*, [www.bitcoin.org](http://www.bitcoin.org), (2008)
- Satoshi; et al., *"Bitcoin source code - amount constraints"*, (2016)
- Satoshi, L.. *"Who is Satoshi Nakamoto?"*. The Economist. The Economist Newspaper Limited, (2012)
- Wilson, Thomas, *"Twitter and LinkedIn ban cryptocurrency adverts – leaving regulators behind"*, (2018)
- CNN Money *"What is Bitcoin?"*, (2015)
- RFID, or Radio-frequency identification is a wireless non-contact system that uses radio-frequency electromagnetic elds to transfer data. Source: <http://en.wikipedia.org/wiki/RFID>

## Management of succession in family businesses

Claudia Isac\*

*University of Petrosani, 20 Universitatii str., Petrosani 332006, Hunedoara County*

---

### Abstract

In the introduction of this paper, we have revealed a few issues relating to the development of family businesses in Romania and the necessity of implementing a management of succession in businesses set up after 1990. Thus, using statistical methods we have highlighted their evolution based on several criteria and by comparing them with EU and US models I have created a profile of their successor. Considering that the majority of businesses in Romania are at a stage of being handed over to next generations, we have managed to bring out the defining elements of implementing an efficient management of succession/generations with direct implications on the continuation of the company's activities, the types of succession processes and management principles applied within Romanian companies. At the end of the paper we have compared the successor's profile from the Romanian business environment with the U.S. successor's profile using data gathered from Forbes charts.

*Keywords:* family businesses; management of succession; entrepreneurship.

---

### Introduction

Most of the existing businesses in the current business environment can be treated as a family business, from small companies and medium-sized enterprises to multinationals with a turnover of million euros.

In the academic literature in Romania, the term 'family business' is not very common, on the one hand due to the fact that after 1990 people had a wrong attitude towards businesses, as there was the tendencies to believe that it was a fraudulent way to make a fortune and on the other hand, specialists were more interested in analysing other economic concepts which were more obvious. "Family Business" is a term that has become very common in the current language, but very little analysed and studied in Romania and, generally, *the family business* is a form of economic organization, consisting of an individual entrepreneur and his family, therefore in order for a business to be a family one, it must have three coordinates such as the family, shareholding and the business. A completely different situation can be found worldwide where there are multiple approaches regarding this concept, culminating with magazines and associations that have multiple and intense interests in this respect. It is generally accepted that the family's involvement in the business makes the family business unique; but the literature continues to have difficulty defining the family business.

Traditionally, the family business can be understood as a combination of terms - family and business. There are differences between theoretical and operational definitions (Chua et al., 1999). If we are looking for a theoretical definition, one can put it as the intention of the family to be in control, or maybe as one with the unique, inseparable, synergetic resources and capabilities arising from family involvement and interactions (Habberson et al., 2003)

An operational definition has focused on a combination of the four components involved in the family's involvement in the business, namely ownership, governance, management and trans-generation succession (Machado & Melo, 2014).

It is worth mentioning the definition of the concept given by Professor Jean Davis who stated that the family enterprise is the collection of a family's economic interests and meaningful activities that help to identify, support and unite the family.

---

\* Corresponding author. Tel.: +40-722-878-719.  
E-mail address: isacclaudia@gmail.com

In conclusion, the definition of the concept and the characteristics of the family business are influenced directly by the family involvement in ownership and management which makes the family business to differ from other types of business.

### Comparative analysis of theories about family businesses

Family Business Network Romania Association shows that a family must meet several criteria: at least one member of the family is involved in the management of the company; companies should be listed on the stock exchange; the person who founded or acquired company or his family must own at least 25% of the decision-making rights to which they are entitled to through the holding of equity; the majority of the decision rights belong, directly or indirectly, to the founder or to the spouse, parents, children or direct heirs.

After several studies, it has been established that family businesses are superior to non-family businesses in terms of profits, productivity and other indicators of profitability. When the business is a family business and it is owned entirely by the members of one family, they have common goals and together they invest time and effort into their entrepreneurial development. As a result, high performance is a strong point that family businesses have.

As in any type of business there are disadvantages which may be related to management efficiency, the relations with relatives but also to how financial resources are shared between family members because sometimes their unbalanced contributions may lead to conflicts that affect both the business and family life. Management and family business challenges have resulted in the emergence of two theories on the family business, they either focus on the family, or on the business (Văduva et al., 2011).

*Over-focusing the attention on the business* results in the deterioration of the relationship with the family; its affects communication and feelings within the family, the emotions of the family and it reduces family time especially when only one part of the family is involved in the management of the business.

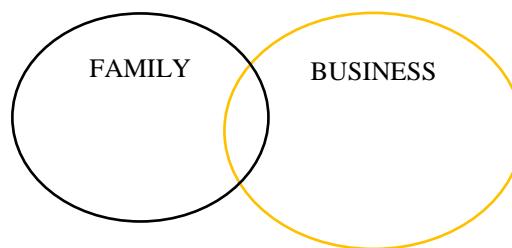


Chart 1

*Over-focusing the attention on the business*

It is obvious that this theory has a counterpart due to over-focusing one's attention on the family which causes communication disruptions within the business, it influences negatively the decision making process and can lead, in the end, to spoiling business relations.

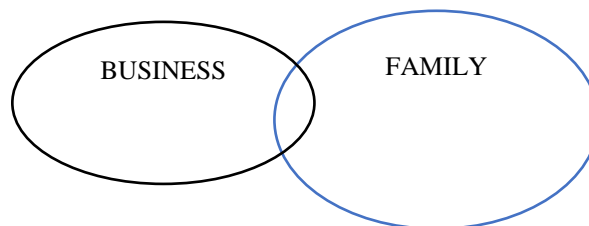


Chart 2

*Over-focusing the attention on the family*

Family businesses ensure the needs and well-being of the family and, in general, their management focuses on resistance more than performance and they stock up on surpluses available during periods of prosperity in order to increase their chances of survival during periods of recession. In this context, the strategic management implemented has certain characteristics. For example, even though the Chief Executive of a family-run company may have financial incentives similar to those of the Executive Directors of non-family businesses, their strategic decisions are influenced by the obligation to the family that will lead to very different strategic options. Thus, the period of time needed for the implementation of strategies varies between 10 or 20 years, while the objectives are focused on what one can build now so that future generations will take advantage of (Kachaner et al., 2012).

In essence, one can point out several differences in the strategic management of family and non-family businesses. The specific elements that influence the strategy in a family business are (Kachaner et al., 2012):

**1. Systemic components.** The family business is a complex system consisting of three subsystems: the family, the shares and the business. Thus, strategic risk arises primarily due to blockages that may appear on the part of the "family" subsystem which in the case of non-family companies is inexistent and the two subsystems balance each other out;

**2. The value of debts.** In modern corporate finance, a considerable value of debt is considered a good thing, because the financial lever maximises the newly created value. In family businesses the notion of debt is associated with the concepts of risk and fragility, and the debt is deemed to be an obstacle which provides a "restricted operating space". Obviously, debts are not totally excluded; it is just that the optimal value of the debt is linked to the attitude towards investment risk and with a short term of repayment. The maximum amount of debt in the case of family-run businesses is 37% of the equity, while non-family firms often reach the threshold of 47% of their capital.

### **3. Expansion policy**

In general, in family businesses, the expansion policy involves purchases of smaller value and/or size in areas relating to existing activities or transactions with a simple geographical expansion that generates organic growth. Most small and medium-sized family businesses avoid high risk transactions based on "radiant" acquisitions. There are, however, exceptions to this rule — when the family is convinced that the traditional sector is faced with structural changes or when it is considered that the business does not take part in the consolidation of the industry and might endanger the long-term survival of the company. On average, it was found that the average value of acquisitions is worth only 2% of the turnover, compared with non-familiar businesses that made purchases of 3.7%, which is almost twice as much.

### **4: Capital expenditures**

Family-run businesses are particularly judicious when it comes to capital expenditures, also called CapEx which represents money invested by a company in the acquisition, maintenance or improvement of fixed assets, such as be property, buildings, factories, equipment and technology. Often, in the context of family businesses one must make sure that these costs are balanced in relation to the cash flow in order to create a surplus for times of recession.

### **5. Personnel policy**

If one analyses the financial indicators in the last economic cycle, i.e. in a crisis, it is observed that family businesses have entered the recession with minimum cost structures and thus the likelihood of implementing restructuring policies and laying off staff is low. Passing on family values has a direct effect on personnel policy and it is mainly focused on complying with principles of ethics and social responsibility, employees are not just names on the payroll or a bar code on an access card.

**6. Strategic planning.** In family businesses strategic planning can be done over a period of 20 years so that an effective strategic planning will have beneficial effects on the following generations (Kachaner et al., 2012).

In conclusion, a family firm is a firm dominantly controlled by a family with the vision to potentially sustain family control across generations (Zellweger, 2017).

## **Management of succession**

One of the most important factors in the continuity of a family business is the implementation of succession management for the transfer of property between generations. The academic literature has examined characteristics of successors and founders, succession processes, and the influence of other family members on succession (Blumentritt et al., 2012).

Succession planning is beneficial to the business, and from this perspective, specialists appreciate that the most important challenge for this type of business is the test of time. A study by John Ward in 1987 concluded that, statistically, only 30% of family businesses are taken over by the second generation, 13% are passing on to the third generation and only 3% survive to be taken over by the fourth generation.

The topic of business continuity is therefore of paramount importance, which any family business leader has to consider. Early preparation of the successor / successors and the definition of a medium to long-term action plan, with or without the help of a specialist, should be a priority.

The succession in family businesses is a process that takes place over a long period of time. Le Breton-Miller et al. (2004) regarded succession management as a complex process with four main stages: establishing basic rules, cultivating and training the group of potential successors, selecting successors and establishing the final successor. Most research on the succession family businesses focuses on the second stage regarding the cultivation and training of the group of potential successors, while the other focuses on the final step following the selection (Mazzola et al., 2008; Mitchell et al., 2009). In most studies, the succession is a risk period of survival for a family (Royer et al., 2008 Shepherd & Zacharakis, 2000) and one of the main reasons for the high rate of failure among family businesses first and second generation is the inability to manage the emotional aspects of the succession process (Blumentritt et al., 2012). They have made an inventory of many studies conducted by various researchers in family businesses domain and have shown that they have not found any study exploring specific decision-making procedures for succession management and which could include decisions on the choice of successor.

The fundamental challenge of any family business is, on the one hand, the tension between business needs for growth and development and, on the other hand, the family's interests for continuity, succession and preservation of its vitality. Succession management is influenced by elements specific to family governance. In most cases, the family needs resources to support itself, while the business needs funds for investment and expansion, and the adoption of a form of governance allows the adoption of clear procedures that apply when conflicts and misunderstandings arise between family and business.

In terms of succession management, two governance models considered to be most effective are generalized:

1) Establishment of an Administrative Board made up of independent members, with no business or family interests, but with a large business experience and who may make the founder and / or successor be more accountable. Practice has shown that family businesses with the Board of Directors are growing faster, are more active on international markets, and the probability of following a succession plan is greater;

2) Creating a family governance structure before moving to the second generation and avoiding subjective choices in judging hiring other family members or choosing the successor. For example, in the Raventos family, who runs the Condorniu Group of Wine Producers in Spain, family members have known since childhood conditions for becoming employees: English knowledge, university degree and experience of at least five years in a another company.

### Succession management studies

Concerning the results of studies comparing sustainability reporting practices between family firms and non-family firms, two orientations are observed: the undifferentiated orientation of the results on the sustainability of family and non-family businesses and differentiated orientation through which the studies suggests that there are more differences in the sustainability of family and non-family businesses.

This topic was also addressed in the 2015 and 2017 Romanian Family Barometer, edited by EY Romania. The 2017 study was applied to 247 businessmen involved in family businesses who responded from the 27 online questionnaire questions from February 8 to March 5, 2017. Of these, 80 are family-run businesses with a turnover exceeding EUR 1 million.

From the perspective of those questioned, the business succession planning is done taking into account the following elements: 100% of Romanian entrepreneurs with family businesses with incomes of over 1 million euro have identified successors, compared with only 87% globally; on a global level, the Board of Directors is most often responsible for the succession (44%), followed by owners and CEOs, unlike Romania where the owners are responsible in 78% of succession management, followed by the CEO (15%) and Board of Directors (5%).

The answers in the case of identification of the person responsible for planning the succession remain similar to those in previous editions of the survey. In conclusion, more than 3/4 of respondents believe that the owners are the ones planning succession, followed by General Director and the Board of Directors.

### The economic importance of family businesses

In Europe, the over 14 mil family businesses that turn out around 50% of the GDP have generated over 60 million jobs, approximately 40%-50% of the total employment figure. Comparisons between different countries show different shares of family businesses in the total of companies, ranging between 38-90%. Research demonstrates that, in Denmark, all family businesses are SMEs, and nearly 80% of them have less than 25 employees. A similar situation can also be found in Finland, and Ireland, where 98% of the family businesses employ less than 50 workers. In Lithuania, more than 90% of family businesses take on up to 9 persons, and the rest, about 10% are small businesses with less than 50 employees. In terms of turnover, it is noted that the share of family businesses with an annual turnover of over EURO 2 million in the total of companies is different in Europe, ranging from significant percentages, such as 18% in Italy and 16% in the United Kingdom while lower percentages have been recorded in Spain 7% or Sweden 4%.

Statistical data collected by the European Family Businesses show the impact of the activities of the family businesses on local economies, national economies, international relations and even on the process of globalization. In detail, the most important key figures regarding the share of family businesses in the total of the European companies are summed up in the following chart. Countries like Estonia and Slovakia have taken the lead with 90%, the Czech Republic with 87%, or Spain with 85% while other countries which have registered smaller percentages, such as Lithuania 38%, Latvia 58% or Romania 65% prove to have a deficient entrepreneurial education system due to communism that ruled out the notion of private property in favour of equal incomes among citizens. Even though over 96% of all family businesses are SMEs, including family farms, the difference is made by great family-run businesses by being in the top European and international companies.

Statistical reports on *The Statistics Portal* show that the most important family businesses in Europe with an impressive market value which allows them to maintain their top position as the biggest businesses for many decades are reputable businesses with a major influence on the world's economy, such as Roche from the Netherlands, BMW and Volkswagen from Germany or Anheuser-Busch InBev from Belgium.

A suggestive picture relating to family businesses can be formed on the basis of the research *undertaken for the drafting* of Top Forbes 100 for the year 2018, and it reveals that there are three European family businesses run by women: the French Françoise Bettencourt Meyers (L'Oréal, ranked 18th), the German woman Susanne Klatten (BMW, 32nd place) and the Dutch Charlene de Carvalho-Heineken (Heineken, ranked 86th) and the youngest billionaire in the world is also a woman, the Norwegian Abbas Abid, aged 21 years, with a wealth of \$1.4 billion ranked 11th in Norway.

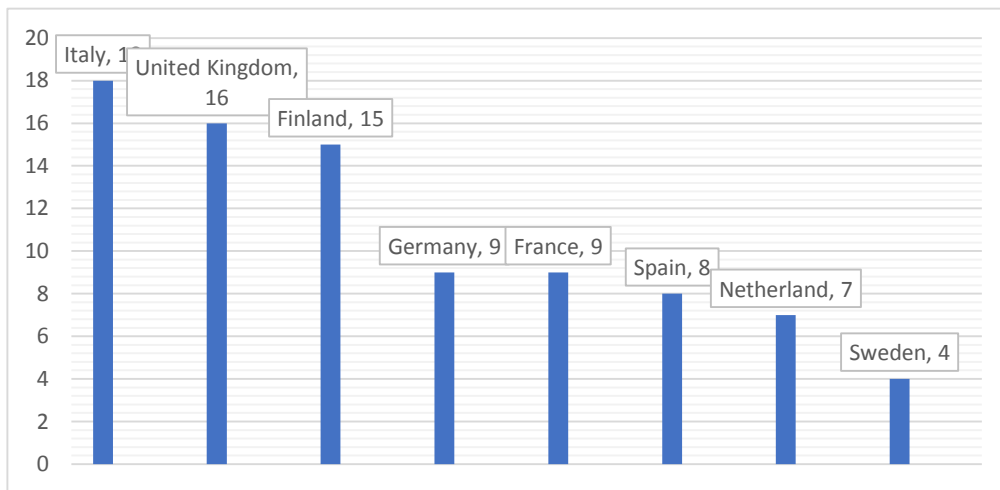


Fig. 1. Annual turnover of over EURO 2 million in the total of companies

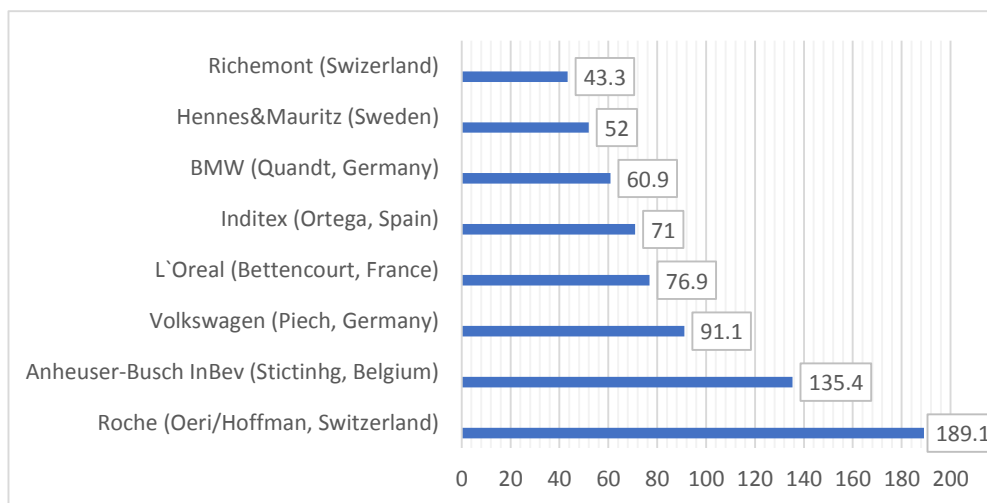


Fig 2. Largest family businesses ranked by market capitalization in Europe (billion euros)

Some of the world's largest family-run businesses are Wall Mart (United States), Volkswagen (Germany), Samsung Group (Korea) and Tata Group (India). According to the study carried out by Sarah Anderson and John Cavanagh within the *Top 200* researches: *Explosion of Global Corporate Power* Wall Mart is the biggest family business, and the added value of this company exceeded the gross domestic product of some national economies such as Poland or Greece (Anderson & Cavanagh).

## Conclusions

In conclusion, family businesses are among the biggest and most sustainable businesses in the global economy, managing to remain innovative, flexible, focused on what they're doing and on growth for decades, if not centuries. The story of each successful family business starts with someone who had the passion, courage and confidence to invest in their own ideas. Entrepreneurs are creative and willing to reach their goals, they have the ability to see business opportunities where others cannot.

Family businesses are the most popular and they play an important role in many countries and are also the foundation of the world's economic development through the creation of numerous jobs which results in a stable and prosperous social life. Most family businesses have grown and have become stronger after they have overcome many obstacles and have undergone several stages of development from simple SMEs e.g. ASUS, ACER, or GIANT and long-term strategies have enabled a consistent development. From entrepreneurial point of view, family business turned out to be incubators for entrepreneurs, developing the entrepreneurial culture from one generation to the next. *In conclusion, one can say that family businesses existed, are and will be present as long as mankind will continue to exist and will be the 'glue' that holds to the world's economy together.*



## References

- Anderson, S., Cavanagh, J., *Top 200: The Rise of Global Corporate Power*, Global Policy Forum.
- Blumentritt T., Mathews T., Marchisio G. *Game Theory and Family Business Succession: An Introduction*, Family Business Review 26(1), (2012).
- Chua JH., Chrisman J.J., Pramodita S., *Defining the Family Business by Behavior*, Entrepreneurship. Theory and Practice, July, (1999).
- George S. Jr., Bloch A., *What You Can Learn from Family Business*, Harvard Business Review, nov., (2012).
- Grabara, J., Dura, C., Drigă, I., *Corporate Social Responsibility Awareness in Romania and Poland: a Comparative Analysis*, Economics & Sociology, Vol. 9, No. 4, (2016).
- Habbershon M.W., Timothy G., MacMillan I.C., *A unified systems perspective of family firm performance*, Journal of Business Venturing, vol. 18, issue 4, (2003)
- Isac C., Dura C., *Strategii de afaceri*, Ed. InfoPlus, Petroșani, (2009)
- Kachaner N., Stalk G., Jr. Bloch A., *What You Can Learn from Family Business*, Harvard Business Review, nov, (2012).
- Machado C., Melo P., *Effective Human Resources Management in Small and Medium Enterprises: Global Perspective*, IGI Global, USA (2014).
- Mazzola P., Marchisio G., Astrachan J.H., *Strategic Planning in Family Business: A Powerful Developmental Tool for the Next Generation*, Family Business Review, vol.21, issue 3 (2008).
- Mitchell R.J, Timothy A.H., Townsend D.M., *Becoming the Boss: Discretion and Postsuccession Success in Family Firms*, Entrepreneurship Theory and Practice 33(6), November (2009).
- Royer S., Simons R., Boyd B., Rafferty A., *Promoting Family: A Contingency Model of Family Business Succession*, Family Business Review, vol.21, issue 3 (2008).
- Sheperd D.A., Zacharakis A.L., *Structuring family business succession: An analysis of the future leader's decision making*, Entrepreneurship Theory and Practice 24(4), (2000).
- Văduva A.S., Văduva L., Fotea S. Fotea I., *Afaceri de familie. Cum să-ți transformi familia dintr-o povară într-o comoară*, Editura Universității Emanuel din Oradea, (2011).
- Zellweger T., *Managing the Family Business: Theory and Practice*, Edward Elgar Publishing, (2017)
- [www.codorniu.com](http://www.codorniu.com)
- [www.ey.com](http://www.ey.com)
- [www.europeanfamilybusinesses.eu/](http://www.europeanfamilybusinesses.eu/)
- [www.statista.com](http://www.statista.com)
- KPMG-Family-Business-Barometer-2017
- EY-Family-Business-Barometer. Romania-2017

## Some Practical Tools to Mitigate Occupational Safety and Health Risks within the Industrial Environment

Ana Petrina Păun<sup>a\*</sup>, Mirela Monea<sup>a</sup>, Codruța Dura<sup>a</sup>

<sup>a</sup>University of Petroșani, University Street No. 20, 332006, Romania

---

### Abstract

The paper reviews the methodological framework for assessing occupational risks and employs the analytical approach in order to estimate workplace accidents and health risks. Occupational risks are determined in a classic manner through taking into account the probability of occurrence of an unwanted event in the industrial environment, multiplied by the maximum predictable consequence of the event. The method applied within our case study aims at quantifying workplace risks within a Romanian company specialized in producing paints, varnishes, removers and accessories, at identifying the risk factors affecting the production system and at computing the actual level of risks on the basis of the severity and frequency of maximum expected loss. The results of the determinations make possible the drawing out of a mix of preventive organizational measures in order to mitigate the accident risks or to narrow down work circumstances that are likely to generate casualties and/or work-related diseases.

*Keywords:* occupational safety and health; risk management; risk assessment matrix; risk analysis and mitigation

---

### 1. Methodological Framework for the Assessment of Occupational Safety and Health Risks

Regardless of their field of activity and their size, corporations are nowadays confronted with various categories of risks, which can seriously impact both the achievement of their operational objectives – activities, processes, technological flows – and the financial outcomes, market performances or reputation. This is why risk management represents a relatively new concept, which was coined in literature due to the prerequisites that condition companies' efficient operations under the circumstances of minimizing the impact of uncertain events on objectives' achievement process and of drawing up possible measures programs for the recovering of sensible areas of activities.

Therefore, under the Occupational Health and Safety procedures, risk management designates a logical, step-by-step process of identifying, assessing and eliminating/ restraining hazards upon the organization's operations, assets and outcomes, followed by monitoring and controlling uncertainties associated with any type of risks. Given the direct link between Occupational Health and Safety Management issues and real life problems that emerged from practical challenges within the industrial environment, expertise in OHS has developed in recent years under the strong influence of academics and practitioners of OHS who sought pragmatic solutions for many particular cases. As a consequence of this trend, the prescriptive literature now overshadows the theoretical debates, aiming at setting up tools, methods and practices rather than substantiating definitions, theoretical models or concepts.

Our paper joins the aforementioned trend, by putting forward a quantitative approach which can be used in order to quantify the level of workplace risks within a Romanian company specialized in producing paints, varnishes, removers and accessories. The essence of the method lies in the identification of risks factors that affect the analyzed system, followed by the assessment of risk magnitude, which represents the product of the degree of gravity and the frequency of maximum expected loss. The output of the evaluation enables managers to conceive, based on previous estimations, a set of preventive technical and organizational measures aimed at reducing those risks of injuries and/or professional health issues which were classified as extremely high and, therefore, unacceptable.

---

\* Corresponding author. Tel.: 0040722363536.  
E-mail address: codrutadura@upet.ro.

The activity assessing professional risks is part of the present legislation regarding labor security and health, namely of *Law no. 319/2006 of Labor Security and Health*, with subsequent changes and completions and of *Romanian harmonized standards EN 12100 and SR EN 1050*, which stipulate the obligation and principles of the risk evaluation of workplaces. Consequently, the two measurable parameters that define risk, in accordance with standard EN 12100:2003, are the following ones:

- *Probability* that may determine an unwanted event (labor accidents or professional illnesses);
- *Severity* of the consequences of the unwanted event, namely the maximum predictable and probable seriousness.

With a view to quantifying these parameters within the context of the analytical methodology for the evaluation of the professional risks which we are going to apply in the case of the company our case study focuses upon, a series of practical work instruments are going to be employed, which will be briefly described below. The first one, **the grid of the parameters evaluating consequences**, classifies these effects in five distinct classes of severity while taking into account the probable effects of possible professional accidents upon the labor capacity of the human resources involved (Table 1).

Table 1. Grid of the parameters evaluating consequences

Severity classes	Consequences	Severity of consequences
1	Insignificant	Minor, reversible consequences with predictable labor incapacity for up to 3 calendar days (recovery without treatment)
2	Minor	Reversible consequences with a predictable labor incapacity ranging between 3 and 45 days, which require medical treatment
3	Medium	Reversible consequences with predictable labor incapacity ranging between 45 and 180 days, which require medical treatment and hospitalization
4	High	Irreversible consequences with diminution of labor capacity of 50 % at least, the individual being able to carry out a professional activity (3rd degree invalidity)
5	Serious	Irreversible consequences with 100 % loss of labor capacity, yet with possibility of self - serving, of self - management and space orientation (2 <sup>nd</sup> degree invalidity)
6	Very serious	Irreversible consequences with total loss of labor capacity, of self - serving, of self - management or space orientation (1 <sup>st</sup> degree invalidity)
7	Maximum	Death

The **probability of unwanted events occurrence** is, at its turn, measured through six categories of distinct events that can be associated to each class of probability: from extremely rare events with a very small occurrence probability (estimated at over 10 years) to events that might occur with a very high occurrence frequency (occurrence probability is considered, in such cases, to be less than 1 month) – Table 2.

Table 2. Grid of the parameters unwanted events occurrence probability

Probability ranks	Event	Probability of consequences - P
1	Extremely rare	(extremely small), $P > 10$ years
2	Improbable	(very small), $5 \text{ years} < P < 10 \text{ years}$
3	Remote	(small), $2 \text{ years} < P < 5 \text{ years}$
4	Occasional	(medium), $1 \text{ year} < P < 2 \text{ years}$
5	Probable	(high), $1 \text{ month} < P < 1 \text{ year}$
6	Frequent	(quite high), $P < 1 \text{ month}$

The **level of professional risk** associated to each event and, implicitly, the **extent to which the objectives of occupational security are or are not met** is measured owing to the grid quantifying the level of risk, displayed by Table 3, which observes the estimated values afferent to risk R, with a variation range between 1÷42. Meanwhile, the colors and fields shown by Table 3 allow the identification of acceptable risks and their separation from the values of unacceptable risks.

In accordance with the identified and classified levels of risks displayed in Table 3, a series of alternatives have been elaborated, which regard the **attitude of decisional factors when facing risk** and the categories of measures that should be adopted in the case of each particular situation – Table 3.

Figure 1 displays the matrix of risk analyzer resulting from the combination of the seven classes of consequences severity appreciated together with the occurrence probabilities associated with each of them. The content of the matrix shows various levels of risk R, in relation with which the evaluation of professional risk is displayed both as a value

(within the variation field  $1 \div 42$  taken into account) and as a color, as each type of color is associated with a higher or lower degree of risk.

Table 3. Grid measuring the level of risk

Levels of risk/ security	Estimation values of risk R	Evaluation of professional risk level	Evaluation of occupational security level
1 / 7	$1 \div 7$	Minimal risk	Maximal security
2 / 6	$8 \div 13$	Very low risk	Very high security
3 / 5	$14 \div 21$	Low risk	High security
4 / 4	$22 \div 29$	Medium risk	Medium security
5 / 3	$30 \div 35$	High risk	Low security
6 / 2	$36 \div 39$	Very high risk	Very low security
7 / 1	$40 \div 42$	Maximal risk	Minimal security

Legend:











					Represents the field of acceptable risk
					Represents the field of unacceptable risk

Table 4. Managers' attitude when facing the identified level of risk

Levels of risk	Evaluation of professional risk	Attitude when facing the level of risk
1	Minimal risk	No special actions are taken
2	Very low risk	
3	Low risk	
4	Medium risk	Monitoring of dangerous situations, control of risk factors occurrence, implementation of supplemental corrective measures while observing the relation cost-efficiency
5	High risk	Efforts with a view to decreasing the level of risk; nonetheless, the level of prevention costs should be carefully monitored. The measures decreasing the level of risk are implemented during strictly determined periods of time. In the case when high risk is associated with serious consequences, they should settle the exact probability of risk factors occurrence in view, and measures should be taken with a view to eliminate them.
6	Very high risk	Activity cannot be carried out until the level of risk decreases! Resources should be allocated with a view to decreasing risk. In the case when other risks come out during the labor process, quick measures should be taken.
7	Maximal risk	Activity cannot be resumed until the level of risk decreases! In the case when the immediate decrease of this level of risk is not possible, then work in such conditions IS FORBIDDEN!

		. CLASSES OF PROBABILITY " P "					
		1 ↓	2 ↓	3 ↓	4 ↓	5 ↓	6 ↓
CLASSES OF SERIOUSNESS " G "	CONSEQUENCES	HARDLY EVER	QUITE RARELY	RARELY	LOW FREQUENCY	FREQUENT	VERY FREQUENT
		P > 10 years	5 years < P < 10 years	2 years < P < 5 years	1 year < P < 2 years	1 month < P < 1 year	P < 1 month
7 →	MAXIMAL DEATH	21	29	35	39	41	42
6 →	VERY SERIOUS 1 <sup>ST</sup> DEGREE INVALIDITY	20	28	34	37	38	40
5 →	SERIOUS 2 <sup>ND</sup> DEGREE INVALIDITY	19	26	27	32	33	36
4 →	HIGH 3 <sup>RD</sup> DEGREE INVALIDITY	13	18	24	25	30	31
3 →	MEDIUM ITM 45 – 180 DAYS	11	12	16	17	22	23
2 →	LOW ITM 3 – 45 DAYS	7	8	9	10	14	15
1 →	UNIMPORTANT	1	2	3	4	5	6

Fig. 1. Risk Assessment Matrix

In the case when, after having evaluated the risks regarding the security and health of the employees, they identify a high risk factor showing that the company operates within the unacceptable area then the **Form for the analysis and decrease of unacceptable risks** should be elaborated. The form will approach and extensively describe the following aspects: description of the *main causes* having determined the occurrence and manifesting of that risk; *possible*

*dysfunctions* that might be determined by that factor; *technical and organizational measures* that should be taken with a view to decreasing/ eliminating the risk; *legal references and documents* owing to which these measures are grounded; *the concrete manner of implementing the proposed technical and organizational measures*, namely: *estimating the probable residual risks* that may occur within the industrial context in view. In order that the risk evaluator might forge a global image of all the categories of partial risks that were shown by the analysis at different work places and jobs within a company, an *Index of the forms for the analysis and diminution of risks* may be conceived; the index will draw out an inventory of all the risk factors classified as unacceptable from the point of view of their magnitude; in accordance, it is possible to elaborate a coherent and unitary *plan of technical and organizational measures* that makes possible the implementation of an efficient risk management with immediate results in the area of increasing the level of health and security of the employees.

## 2. Case Study: The Use of Risk Assessment Matrix within an Industrial Company

We have chosen as an example capable of showing the manner of implementing the instruments of analysis of the risks described by the previous paragraph, a Romanian company which operates in the domain of the technology of paints and varnishes and detains the position of regional leader in this field in the area of South - Eastern Europe. Emerged from the fusion between a local company and a company having a similar object of activity, which used to operate in Bulgaria, Policolor – Orgachim Company conceives and provides full solutions for the consumers on the market of goods, for industrial consumers, and for clients in auto vehicles industry.

The evaluation of the risks at work places and jobs within the company was made for all organizational sub-divisions, irrespective of their having an operational or functional role within formal organization. The level of risk was estimated through the two parameters described by the previous section, namely the *probability of the occurrence of the danger generating the risk* and the *maximum predictable consequences for human organisms*, in accordance with the scale of ranging the level of risk/ security, shown by Table 4:

Levels of risk/ security	Values of risk R estimation	Evaluation of the level of professional risk	Evaluation of the level of occupational security
1 / 7	(1,1) (1,2) (1,3) (1,4) (1,5) (1,6) (2,1)	Minimal risk	Maximal security
2 / 6	(2,2) (2,3) (2,4) (3,1) (3,2) (4,1)	Very low risk	Very high security
3 / 5	(2,5) (2,6) (3,3) (3,4) (4,2) (5,1) (6,1) (7,1)	Low risk	High security
4 / 4	(3,5) (3,6) (4,3) (4,4) (5,2) (5,3) (6,2) (7,2)	Medium risk	Medium security
5 / 3	(4,5) (4,6) (5,4) (5,5) (6,3) (7,3)	High risk	Low security
6 / 2	(5,6) (6,4) (6,5) (7,4)	Very high risk	Very low security
7 / 1	(6,6) (7,5) (7,6)	Maximal risk	Minimal security

*The level of global risk ( $N_r$ ) afferent to the work place* is calculated as a weighted average of the levels of risk settled for the risk factors identified as active in the case of that work place. In order that the result obtained mostly comes near to reality, a weighted average element is employed, that is the rank of risk factor.

$$N_r = \frac{\sum_{i=1}^n r_i R_i}{\sum_{i=1}^n r_i} \quad (1)$$

where:  $N_r$  = the level of global risk per work place;  $r_i$  = the rank of risk factor „i”;  $R_i$  = the level of risk afferent to the risk factor „i”;  $n$  = the number of risk factors identified at the work place.

In the case of the work places and jobs within the company for which we have elaborated this case study, a series of organizational sub-divisions have been identified; after the evaluation of risks, these sub-divisions appeared to range within the area of unacceptable risks. The instrument owing to which the “sensitive points” in view have been identified was the risk analyzer whose matrix was displayed by Figure 1. After having taken into account these aspects, we went further to implementing the procedure of analysis and decrease of these risks through conceiving a coherent program of technical and organizational measures with a view to preventing and fighting the causes that determined the undesired events (labor accidents and professional illnesses). As an example, we are going to display below the form for the analysis and decrease of unacceptable risks determined for the Environment Department.

Focusing upon the technical and organizational measures systematized by their analysis form, a consecutive decrease of the level of professional risk initially quantified at 24 (which matches a degree of risk appreciated as *medium*) towards level 18 is estimated (which matches a *low* degree of risk), so that, at the end of the implementation period, a value equal to 13 could be reached, implying that the activities carried out at the level of this Department will move towards the *area displaying a very low risk*, while the level of security and health of the employees will increase in accordance.

ANALYSIS AND DECREASE OF RISK				
<b>Work place (sub-system):</b> Environment Department/ Textile washer				
<b>Document no.</b> 1	<b>Risk:</b> Medium	<b>Level:</b> 4		
<b>Determined risk ranging within the unacceptable area</b>		<b>P</b>	<b>G</b>	<b>Estimation/ evaluation of risk R</b>
		3	4	24 Medium
<b>Appellation of identified risk:</b> factors of physical risk <b>Description of the identified risk factor (concrete form of occurrence):</b> F36. Noise produced during the functioning of orbital polishing. <b>Causes:</b> <ul style="list-style-type: none"> <li>- Use of washing equipment that is physically and morally out-dated;</li> <li>- Lack of required revision/ repairs;</li> <li>- Improper/ insufficient training of serving employees.</li> </ul> <b>Dysfunctions:</b> <ul style="list-style-type: none"> <li>- Existence of out-dated pieces or of malfunctioning;</li> <li>- Improper or poor exploitation of the washing equipment;</li> <li>- Consequences upon the integrity and health of serving employees.</li> </ul>				
<b>Possible technical and organizational measures:</b> <u>Technical measures</u> <ul style="list-style-type: none"> <li>- Replacement of out-dated pieces belonging to the noise-generating equipment;</li> <li>- Use of equipment certified for the destination and environment they were meant for;</li> <li>- Carrying out periodical measurements concerning the level of exposure to professional noise with a view to evaluating the risk of noise exposure and risk for hearing handicap (document of noise security);</li> <li>- Settling the signaling of noise security and health in accordance with the noise security document;</li> <li>- Providing proper EIP;</li> <li>- Studies concerning the elaboration of technical solutions for decreasing the source level of noise (active measures) or for protecting the employees within their labor environment (passive measures).</li> </ul> <u>Organizational measures</u> <ul style="list-style-type: none"> <li>- Training the employees with a view to becoming aware of the importance of observing work instructions and SSM and of the proper signaling of the workers exposed to professional noise;</li> <li>- Decreasing the period of employees' exposure to noise through work schemes with limited exposures to those operations generating dangerous levels of noise for their health.</li> </ul>		<b>References:</b> Law no. 319/2006 Wok instructions Dangerous substances security forms Applicable standards Study regarding the evaluation of security and health risks at the work places and jobs within Policolor - Orgachim		
<b>Implementation of technical and organizational measures:</b> <ul style="list-style-type: none"> <li>- Replacement of out-dated pieces belonging to the noise-generating equipment;</li> <li>- Use of equipment certified for the destination and environment they were meant for;</li> <li>- Carrying out periodical measurements concerning the level of exposure to professional noise with a view to evaluating the risk of noise exposure and risk for hearing handicap (document of noise security);</li> <li>- Settling the signaling of noise security and health in accordance with the noise security document;</li> <li>- Providing proper EIP;</li> <li>- Studies concerning the elaboration of technical solutions for decreasing the source level of noise (active measures) or for protecting the employees within their labor environment (passive measures);</li> <li>- Training the employees with a view to becoming aware of the importance of observing work instructions and SSM and of the proper use of EIP;</li> <li>- Providing the security and health signaling to the employees exposed to professional noise;</li> <li>- Decreasing the period of employees' exposure to noise through work schemes with limited exposures to those operations generating dangerous levels of noise for their health.</li> </ul>		<b>References:</b> Law no. 319/2006 Wok instructions Dangerous substances security forms Applicable standards Study regarding the evaluation of security and health risks at the work places and jobs within Policolor - Orgachim		
<b>Identifying residual danger:</b> Possibility of the washing equipment becoming out-dated and possible malfunctioning of its components parts.		<b>P</b>	<b>G</b>	<b>Estimation/ evaluation of risk R</b>
		1	4	13 Very low
<b>Residual risk:</b> Carrying out the labor task owing to the washing equipment.		<b>Actions:</b> Decreasing the risk from 24 (level 4) to 13 (level 2) through implementing technical and organizational measures, in accordance with Figure 3.		

Fig. 2. Form for the analysis and decrease of unacceptable risks – Environment Department

(Source: Study on Safety and Health Risk Assessment for Workplaces and Workstations within Policolor-Orgachim, INSEMEX Petroșani, 2015)

### 3. Conclusions

The literature provides practical guidance for managers in order to initiate and make improvements in the process of industrial risks assessment. A mix of variables, risk factors, triggers and combinations must be taken into account in the process of constructing the most adequate tool that covers the peculiarities of the industrial environment to be applied. No matter if qualitative, semi-quantitative or quantitative, we believe that risk ranking systems will continue to expand and to grow in efficiency, keeping up with managers' necessities related to the process of conceiving an implementing pragmatic and innovative solutions to increase the level of security for their workplaces.

	1 ↓	2 ↓	3 ↓	4 ↓	5 ↓	6 ↓
CLASSES OF SERIOUSNESS " G "	CLASSES OF PROBABILITY " P "					
7 →	21	29	35	39	41	42
6 →	20	28	34	37	38	40
5 →	19	26	27	32	33	36
4 →	← 13	← 18	← 24	25	30	31
3 →	11	12	16	17	22	23
2 →	7	8	9	10	14	15
1 →	1	2	3	4	5	6

Fig. 3. Diagram of decreasing the professional risk associated with the risk factor

## References

- Băbuț, G.B., Moraru, R.I., Cioca, L.I., „Kinney methods”: Useful or Harmful Tools in Risk Assessment and Management Process?, *Proceedings of the 5th International Conference on Manufacturing Science and Educations (MSE 2011)*, Vol. II, pp. 315-318, Sibiu, Romania, (2011).
- Băbuț, G.B., Moraru, R.I., Dura, C., Conceptual and Methodological Framework for risk analysis and evaluation on Seveso Industrial Sites (I) Risk Evaluation Terminology, Objectives and Stages, *Quality - Access to Success*, Vol. 16, No. 145, pp. 111-116, (2015).
- Băbuț, G.B., Moraru, R.I., Dura, C., Conceptual and Methodological Framework for risk analysis and evaluation on Seveso Industrial Sites (II) Critical-comparative Study and Development of New Approaches regarding the Risk Analysis and Evaluation Methods, *Quality - Access to Success*, Vol. 16, No. 146, pp. 103-112, (2015).
- Dura, C., Păun, A.P. Moraru, R.I., Empirical Analysis on the Relationship between Corporate Health and Safety Performance and the Financial Outcome within Socially Responsible Companies, *Quality - Access to Success*, Vol. 19, No. 162, pp. 155-160, (2018).
- Cotigă F., Drăghici, A., Vasilescu, G. D., *Theoretical and Practical Basis regarding the Audit of Occupational Health and Safety*, Promun Publishing House, Arad, (2009)
- Moraru, R.I., *A Treatise on Occupational Safety and Health*, Focus Publishing House, Petroșani, (2013).
- Moraru, R.I., Băbuț, G.B., Cioca, L.I., *Study of Methane Flow in Caved Goafs Adjacent to Longwall Faces in Valea Jiului Coal Basin*, Proceedings of the 13th International Multidisciplinary Scientific Geo-Conference - SGEM 2013, Vol. I, pp. 731-738, Albena, Bulgaria (2013).
- Moraru, R.I., *Current Trends and Future Developments in Occupational Health and Safety Risk Management in Risk Management for the Future - Theory and Cases*, Dr Jan Emblemssvåg (Ed.), (2012)
- Moraru, R.I., Băbuț, G.B., Cioca, L.I., Drawbacks and Traps in Risk Assessment: Examples in Romania, *Proceedings of the 5th International Conference on Manufacturing Science and Educations - MSE 2011*, Vol. II, pp. 363-366, Sibiu, Romania, (2011).
- Moraru, R.I., Băbuț, G.B., Cioca, L.I., Knowledge-Based Hazard Analysis Guidelines for Operational Transportation Projects, *Proceedings of the 15th International Conference the Knowledge Based Organization: Management*, Volume 2, pp. 117-122, Sibiu, Romania, (2009).
- Vasilescu, G.D., Drăghici A. N., Baci, C., Methods for Analysis and Evaluation of Occupational Accidents and Diseases Risks, *Environmental Engineering and Management Journal*, Vol. 7, No. 4, pp. 443-446, (2008)
- \*\*\*, *Study on Safety and Health Risk Assessment for Workplaces and Workstations within Policolor-Orgachim*, INSEMEX Petroșani, (2015)
- \*\*\*, The Law No. 319/2006 on *Occupational Health and Safety* and the Methodological Norms for the application of the Law No. 319/2006
- \*\*\*, SR EN 1050: 2000: *Safety of machines. Principles for risks assessment*
- \*\*\*, EN ISO 12100-1: *Safety of machines. Basic concepts, general principles of design. Key terminology and methodology*.
- \*\*\*, EN ISO 12100-2: *Safety of machines. Basic concepts, general principles of design. Technical Principles*.



# OHS Disclosure in Romania in the Framework of CSR Reporting

Codruța Dura<sup>a\*</sup>, Imola Drigă<sup>a</sup>, Ana Petrina Păun<sup>a</sup>

<sup>a</sup>University of Petroșani, University Street No. 20, 332006, Romania

---

## Abstract

The paper aims to assess the magnitude of OHS disclosure phenomenon in Romania, in the context of CSR and sustainability reporting. In order to achieve our research objective, we have performed a qualitative study, based on the content analysis method. Thus, we have focused on identifying a few cardinal aspects that are able to facilitate a general insight on the issue of OHS disclosure: the novelty of the reporting routine; the core OHS themes presented in the sustainability/CSR reports; the compliance of reports with the international standards, the number of pages dedicated to OHS issues etc. Our outcomes substantiated the idea that the occupational safety and occupational health issues are highly important for managers who activate in the industrial sector and acknowledge the risk of physical hazards occurrence. Moreover, subsidiaries of multinationals operating in Romania, benefit from the experience gained by their parent companies in terms of OHS reporting, but they still have to do a lot of improvements in their practices, in order to comply with the international reporting standards.

**Keywords:** OHS disclosure, CSR reporting, sustainability reports, non-financial reporting, multinational companies

---

## 1. CSR Development and Reporting in Romania – facts and figures

CSR received a great deal of attention in the literature, during the last two decades, being accounted between the most argued topic of the global economy. The significance of the CSR concept and the related practices developed under the pressure of stakeholders towards increasing of transparency and adoption of ethical behavior in business. The main stimulus that set off the occurrence and the proliferation of CS reporting, seem to lose itself among the mechanisms that drove the very development of the international economy (Lungu et al, 2016). The prerequisite of integrating social aspects of business with the financial information occurred in 1970s, when the first non-mandatory reports were issued. In the 1980s the environmental issues became prevalent, due to the high level of risks associated with the impact of economic activities on nature's degradation. Environmental-related risks proved themselves to be capable of even threatening the market survival for numerous of the Globe's largest corporations. Sustainability reporting has spread in the 1990s, when the holistic approach emerged and the *triple-bottom-line* reporting acknowledged the interplay between economic, social and environmental facets of business (Dura et al., 2017).

In Romania, the culture of sustainability reporting is still in the making, under the positive impact of large multinationals that have assumed the role of disseminating managerial practices proved to be efficient in their countries of origin (Grabara et al., 2016). Until the issuance of Order No. 1938/2016 by the Romanian Ministry of Public Finances, both CSR programs and reporting practices were initiated and unfolded rather as discretionary and non-mandatory activities; after the 1<sup>st</sup> of January 2017 when the aforementioned legal act came into force, the majority of the Romanian companies begin to comprehend the topic, while seeking the proper solution to adapt.

In order to have an insight of the status of CSR development in Romania, we are going to use statistical data provided by some representative surveys conducted at the national level by renowned consultancy firms: CSRMedia & Valoria, Ernst&Young, The Azores. Thus, according to the research *Dynamics and Perspectives of CSR Domain in Romania*, conducted in 2018 on a sample of 107 enterprises from 16 industries, the main reason that drives a company's involvement in CSR programmes are represented in figure 1. Unfortunately, CSR is still viewed, by an important share of the analyzed companies, as a component of PR strategy, aimed at disclosing solely favorable appearances. Thus, the same survey reveals that the budget line for CSR is drawn up, for 63% of the companies included in the sample, within the PR&Marketing Department (Figure 2).

---

\* Corresponding author. Tel.: 0040722363536.

E-mail address: codrutadura@upet.ro.

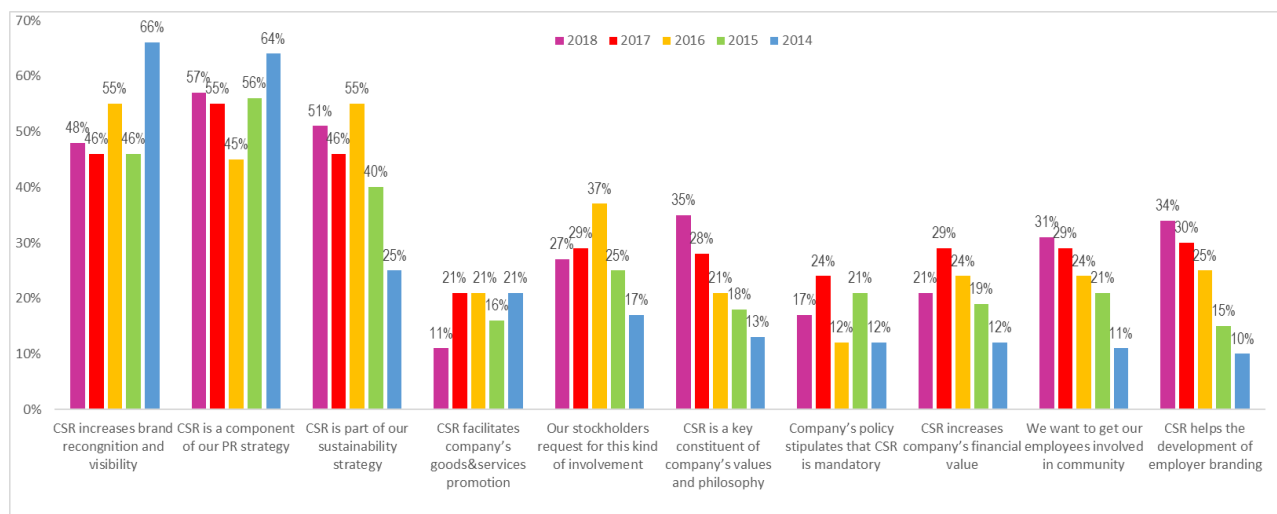


Fig. 1. Main reasons that drive Romanian companies' involvement in CSR  
(Source: *The Dynamics and Trends of CSR Domain in Romania*, CSR Media & Valoria, 2017)

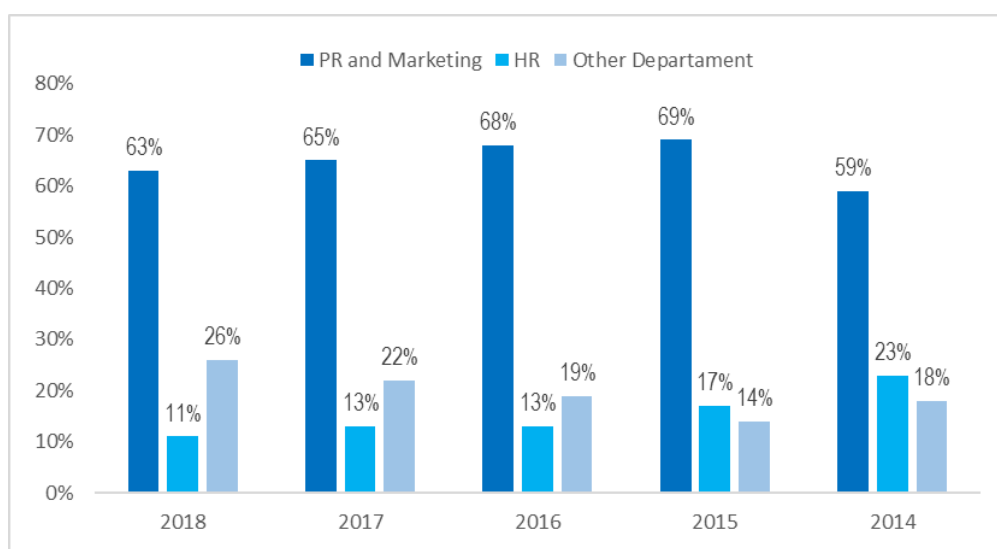


Fig. 2. Departments that draw up the main budget line for CSR  
(Source: *The Dynamics and Trends of CSR Domain in Romania*, CSR Media & Valoria, 2017)

However, it is worth-mentioning that the majority of companies (51%) are beginning to be aware that CSR represents a key component of the sustainability strategy. When it comes to revealing the instruments employed for the public disclosure of CSR activity, we have noticed that annual reports hardly rank the fifth position (34%), after social media (84%), press releases (81%), websites (78%) and CSR dedicated platforms (59%) – figure 3.

Little data is available from empirical studies undertaken in Romania with the focus of CSR communication. But the few proofs we discovered tend to advocate our belief regarding the absence of a strategic approach in CSR communication by the Romanian companies. In fact, except for subsidiaries of multinational corporations, an insufficient number of small and medium enterprises originating from our country have already settled a constant CSR/sustainability reporting practice (Gliogor-Cimpoieru & Munteanu, 2014).

## 2. OHS disclosure in CSR/Sustainability Reports

Promoting transparency and increasing the extent of non-financial business information disclosure constitute vital issues placed on EU's agenda. It has been shown that the Western part of the European continent represents the most committed area when it comes to measuring the magnitude of CSR reporting (Montero et al., 2009). According to *The KPMG Survey of Corporate Responsibility Reporting 2017*, "reporting integration is the new normal and *non-financial* is the new financial".

In other words, if CSR data was regarded in the past as strictly "non-financial" and not enough pertinent to be inserted in the content of annual financial reports, more than three quarters of the world's 250 largest companies incorporate now at least a few non-financial facts and figures in their financial statements.

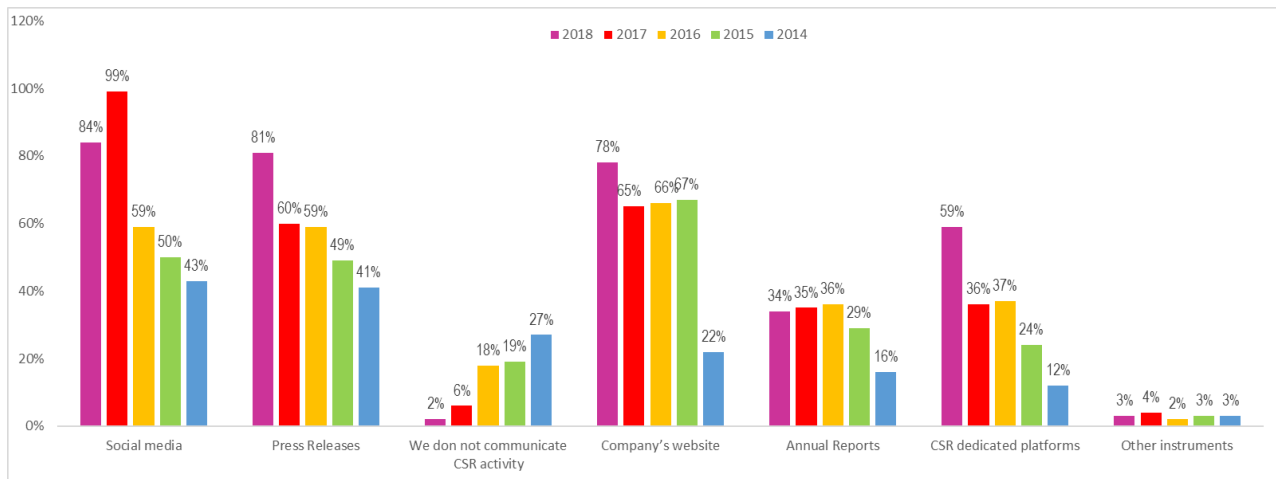


Fig. 3. Instruments employed by the Romanian companies for the public disclosure of CSR activities  
(Source: *The Dynamics and Trends of CSR Domain in Romania*, CSR Media & Valoria, 2017)

Figure 4 shows CSR reporting rates in Western Europe, Eastern Europe and Romania, between 2015 and 2017. Under the pressure of regulation changes and investors' constraints, Romania is included among the group of countries with CSR reporting rates higher than the global average. Thus, it is estimated that more than 700 Romanian companies will have to satisfy requirements stipulated by The Directive 2014/95/EU on Non-Financial reporting, but the estimated synergistic effect for other companies that do not fall under the incidence of this law is expected to be outstanding, due to the benchmarking phenomenon (Ogorean, 2017).

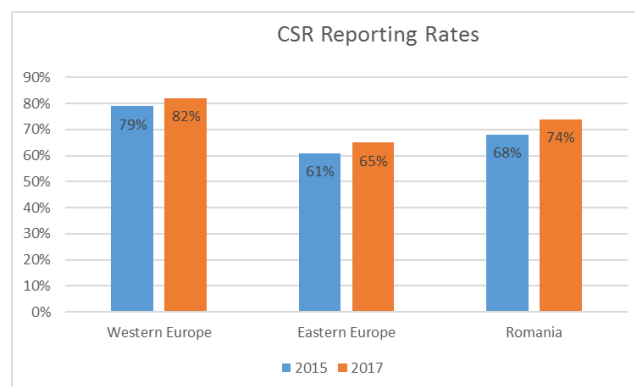


Figure 4: CSR reporting rates between 2015 and 2017  
(Source: *Survey of Corporate Responsibility Reporting*, KPMG, 2017)

In the framework of CSR, employee-related issues received a great deal of attention over the past two decades. Yet, early empirical studies, with very few exceptions, brought little insights when it comes to OHS disclosure topic. The main emphasis of these studies was limited to highlighting the peculiarities related to quantity, quality and communication modes employed for miscellaneous CSR issues (Habek et al., 2016). The common denominator of these researches has resulted in demonstrating high levels of reporting on OHS within the content of annual reports, CSR reports, sustainability reports and websites (the overall frequency was estimated to range between 70% and 95%). (O'Neill, 2010). As the OHS domain flourished, many scholars addressed issues of content and quality in reporting, driven in a certain degree, by the appearance of GRI 403, a customized sub-set of GRI Standards designated to the harmonization of reporting practices in the area. The GRI framework directs both the process a drawing up the sustainability report and, more specifically, the content of the report which is split off in two parts: management approach and topic-specific disclosures. The management approach covers the following issues: *OHS management system*; *hazard identification, risk assessment and incident investigation*; *occupational health services*; *worker participation, consultation and communication on OHS*; *worker training on OHS*; *promotion of worker health*; *prevention and mitigation of OHS impacts directly linked by business relationships*. Topic-specific disclosures refer to the following aspects and key-performance indicators (KPI): *workers covered by an OHS management system*; *work-related injuries* and *work related ill health* (GRI 403, 2018).

In order to provide a wide picture of OHS reporting by the industrial Romanian companies, we have chosen *the content analysis method*. Content analysis concerns the procedure of drawing replicable and valid conclusions from the analysis of a given text (Krippendorff, 2004). Several content analyses of corporate reports were performed in the literature and they have used different units of analysis, such as word count, sentence count, page count or word-level coding with the help of a modern software (Koskela, 2014). Our analysis relies on statistic data collected for a sample

of large industrial corporations that operate in Romania as local companies or as subsidiaries of renowned multinationals (see Appendix A). In the process of sample selection, we have taken into account the research findings of *Romania CSR Index 2018*, a study undertaken at the national level by *The Azores* consultancy agency. The main objectives of the survey were as follows: to bring to the fore the Romanian leading and trendsetter companies in the field of CSR; to strengthen responsible business practices in the context of the IT&C development and the requirements towards competitiveness increasing; to enhance the exchange of good practices between corporations both at the national and international level; to raise the CSR awareness among the business men and policy makers; to build a strong CSR/sustainability professionals network focused on responsible business practices dissemination (The Azores, 2018). The methodology employed by *Romania CSR Index 2018* was aimed at computing the CSR composite Index for each of the 696 companies included in the survey, namely the entire population of companies with more than 500 employees operating in our country. The assessment of CSR Index was based on 49 indicators divided into 9 categories: corporate governance; diversity; company's economic impact; environment; human rights and anti-corruption policies; employees; marketing and creating awareness; community investments and supply chain management. The study has yielded the top 3 CSR players classified by industry: automobiles; banks; beverages; chemicals; computers retail; construction; construction materials; electrical equipment; environmental and facilities services; food products; food retail; gas utilities; hotel restaurant; insurance; machinery; metals/mining; oil&gas; pharmaceuticals and so on.

Keeping the main focus of calling attention on the most responsible companies in Romania and having in mind at the same time the importance conferred to OHS management systems in the industrial field, we performed our content analysis by choosing 10 different companies mentioned in the *Romania CSR Index 2018* from the following industrial sectors: oil&gas; metals and mining; construction and engineering; machinery; chemicals; construction materials; automotive. In order to substantiate our findings, we made use of the following sources of information: CSR and financial reports issued by companies, academic articles and research papers approaching CSR development in Romania, company's websites, on line platforms for CSR programs and other media communications.

Given the national context and the incipient phase of OHS disclosure development, Appendix A was tailored in order to highlight the following aspects: the level of producing the sustainability/CSR report (the company level was colored in green while the group level was pointed out in yellow); year of issuing the first report (in order to see the novelty of the reporting routine); core themes approached from the OHS domain; the compliance of reports with international standards; the number of pages addressing OHS issues and the total number of pages of the report. While going through the process of gathering information and filling in the table 1 from the Appendix A, we were able to have a clear picture regarding the genuine stage of OHS disclosure in Romania. The main findings are summarized below:

✓ Subsidiaries of multinationals benefit from the experience gained by their parent companies in terms of CSR and OHS reporting, in the developed markets. For instance, in the oil&gas industry, OMV Petrom and Rompetrol (a member of Kaz Munay Group) are the only examples of companies which were able to provide sustainability reports in compliance with GRI standards. Thus, according to Database Global Reporting, there were only 5 companies from Romania that issued a non-financial GRI report in 2017, as compared to 98 GRI reporting companies from Italy and 151 GRI reporting corporations from France. Other empirical studies showed that the oil&gas sector ranks in the first place among the most dynamic fields embracing reporting standards, due to the international scope of their business (Filip et al., 2012). Moreover, OMV Petrom's first sustainability report date back to 2011, but the company had already gained in-depth knowledge in reporting, due to its previous CSR communications;

✓ The fact that the majority of the selected companies published their first sustainability reports in 2016 or even in 2017 (Romgaz and Vimetco Alro Group are two of the most relevant examples) demonstrates that the Romanian companies still linger in the incipient phase of reporting. Although Romania lags behind Western countries with respect to sustainability awareness, the widespread adoption of international standards represents an opportunity that could allow our country to align itself to the global routine while skipping some time-consuming learning cycles (Păun&Isac, 2016);

✓ Regarding the themes tackled by OHS dedicated sections of sustainability reports, one can observe that they are generally consonant with the international practices and with the content of GRI 403 Standard for Occupational Health and Safety. Thus, the values of key performance indicators, the description of the work environment, training and education programs, occupational safety initiatives or the diversity and non-discrimination issues are among the most frequently encountered subjects;

✓ The length of sections dedicated to OHS issues shows that, in average, approximately 9-12% of the information provided in sustainability reports addresses the aforementioned field. It is a relatively high proportion that give evidence of the growing interest regarding OHS metrics and policies in our country.

### 3. Conclusions and limitations of the research

Despite the need for further research in the area, a few OHS reporting trends became visible from our analysis. First, the importance of occupational safety and occupational health issues is evident for the industrial companies in the sample, because managers running business in these fields are aware, to a great extent, that their company is undoubtedly exposed to a higher probability of physical hazards occurrence than in other areas. Another factor that fueled this evolution consisted in the process of OHS legislation's improvement, which continuously accompanied

efforts made by corporations in order to comply with reporting requirements. Moreover, the complementary role of occupational health and occupational safety seems to be properly recognized in most of the companies from our sample. On the other hand, the reading of sustainability reports enabled us to see that the companies reported both the outcomes (Key Performance Indicators) and the operations “behind the scene”. In other words, beside the effective management of OHS activities in the workplace, there were developed many internal programs, addressed to employees, that targeted shaping and consolidation of the safety culture.

Authors are also aware that the present paper is subject to some limitations. First of all, using the qualitative content analysis method, inevitably implies to some extent, that the subjectivity of the researchers affects the outcomes. Secondly, it is pointed out in the literature that the process of counting the number of pages assigned to a specific topic within a report addressed to the general public can be unrealistic sometimes, because such reports variably include unnecessary photos that are not always related to OHS issues. However, given the fact that all the companies in our sample have used, averagely, comparable illustrations in their disclosures and the reports’ formatting were very much alike, we concluded that taking into account the amount of pages in order to approximate the level of OHS reporting was sufficiently reliable. Thirdly, another limitation of our research is represented by the fact that our sample cannot be considered representative enough to reflect the overall status of OHS reporting at the national level. We can rather state that our study can be seen as a starting point for an empirical study on the subject, that will involve a larger sample of sustainable-oriented businesses from Romania.

## References

- Dura, C., Drigă, I., Isac, C., Environmental Reporting by Oil and Gas Multinational from Russia and Romania: a Comparative Analysis, *Environmental Management and Engineering Journal*, Vol.16, No. 6, pp. 1269-1274, (2017)
- Filip R., Iamandi I.E., Munteanu S.M., Corporate social responsibility management standards in Romania: Application and evaluation at corporate level, *Business Excellence and Management*, Vol. 2, pp. 35-46, (2012)
- Grabara, J., Dura, C., Drigă, I., Corporate Social Responsibility Awareness in Romania and Poland: a Comparative Analysis, *Economics & Sociology*, Vol. 9, No. 4, pp. 344-359, (2016)
- Gligor-Cimpoieru, D.C., Munteanu, V.P., External CSR Communication in a Strategic Approach, *Economia. Seria Management*, Vol. 17, No. 2, pp.276-289, (2014)
- Ogorean, C., The Directive 2014/95/EU – Is there a New Beginning for CSR in Romania?, *Studies in Business and Economics*, Vol. 12, No. 1, pp. 141-147, (2017)
- O'Neill, *Accounting for Lost Time: Examining Corporate Accountability to Stakeholders for Occupational Health and Safety*, Ph.D. Thesis, RMIT University, (2010)
- Lungu, I.L., Caraiani C., Dascălu, C., Turcu, D., Turturea, M., Archival Analysis of Corporate Responsibility Research: the Romanian Perspective, *Accounting and management Information Systems*, Vol. 15, No.2, pp.341-371, (2016)
- Krippendorff, K., *Content Analysis: An Introduction to Its Methodology*, Sage Publications, Thousands Oaks, (2004)
- Koskela, M., Occupational Health and Safety in Corporate Social Responsibility Reports, *Safety Science*, Vol. 68, pp.294-308, (2014)
- Habek, P., Wolnibak, R., Assessing the Quality of Corporate Social Responsibility Reports: the Case of Reporting Practices in Selected European Union Member States, *Quality&Quantity*, Vol. 50, No.1, pp. 399-420, (2016)
- Montero, M.J., Araque, R.A., Rey, J.M., Occupational Health and Safety in the Framework of Corporate Social Responsibility, *Safety Science*, Vol.47, No.10, pp.1440-1445, (2009)
- Păun, A.P., Isac, C., *Social Security Management*, Universitas Publishing House, Petroșani, (2016)
- \*\*\*, *GRI 403: Occupational Health and Safety*, Global Reporting Initiative, (2018)
- \*\*\*, *Survey of Corporate Responsibility Reporting*, KPMG, (2017)
- \*\*\*, *Romania CSR Index*, The Azores Sustainability&CSR Index, (2018)
- \*\*\*, *The Dynamics and Trends of CSR Domain in Romania*, CSR Media &Valoria, (2017)
- \*\*\*, *Sustainability Reports*, OMV Petrom, Romgaz, Kaz Munay Group, Arcelormittal Galați, Vimetco Alro Group, Electrica SA, Shaeffler Group, Ameropa Group, Heidelberg Cement Romania, Lafarge Holcim Group, Nissan Renault Group, Ford Group, (2017)

## Appendix A

Table 1: Summary of content analysis for a sample of large industrial companies

No.	Company	Industry	Level of the Sustainability Report	Year of first issue	OHS items included	International standards	Pages dedicated to OHS issues	Total number of pages
1	OMV Petrom	Oil & Gas	Company	2011	Management approach to safety; H&S KPIs for 2017; Health programmes and platforms; Health benefits and surveys; Occupational safety initiatives; Safety culture campaigns; Targets for 2018 etc.	GRI G4	10	88
2	Rongaz	Oil & Gas	Company	2017	Employees; Work Environment; Benefits for employees; Professional development and training; Performance Management; Accidents at work; Collective bargaining and Trade Unions; Projects for employees.	-	17	107
3	Rompetrol (Kaz Munay Group)	Oil & Gas	Kaz Munay Gas International	2015	Workforce structure and evolution; Remuneration policy; Rewards and recognition; Employees contribution and market presence; Employees well-being and engagement; Skill management and Life-Long-Learning; Safety performance indicators; Labour practices.	GRI G4	14	103
4	Arcelormittal Galați	Metals and Mining	Company	2017	Description of „4+1 tools” programme which included: the Cardinal Rules; HIRA (Hazard Identification and Risk Assessment); H&S visits aiming at consolidating the safe behaviour; the Ideas of Progress with a significant impact on safety: Take Care Headquarters, training in Health and Safety Management System; Health Week Celebration etc.	-	6	55
5	ALRO	Metals and Mining	Vimetco Alro Group	2017	H&S KPIs for 2017; Training and education; Diversity and inclusiveness; Projects involving employees in finding creative solutions for local communities problems.	-	4	60
6	Electrica Serv Subsidiary	Construction and Engineering	Electrica SA	2016	Employees; Non-discrimination; H&S KPIs for 2017; Programmes to increase Health & Safety at work; Training and education	-	5	51
7	Shaeffler Romania	Machinery	Shaeffler Group	2016	Diversity; Employees advancement Development; Training Data; Ensuring Occupational and Health Safety; Work-life balance; Payment and pensions	-	6	72
8	Azomureș	Chemicals	Ameropa Group	2012	H&S management; Accidents at work; Presentation of KPI system „red label”; Management of emergency situations; Management of Hazardous Chemical Substances and Mixtures (REACH); Product safety and quality assurance	-	3	33
9	Heidelberg Cement Romania	Construction Materials	Company	2004	Occupational Health and Safety – organisation and process; Measures – occupational safety as a management task; Accident figures; Occupational illness; Human resources development; Diversity management; Work-life balance	-	7	62
10	Holcim	Construction Materials	Lafarge Holcim Group	2015	Health and Safety strategy; Accident figures; Auditing Health and Safety performance; Road Safety program; Supporting the health of the workforce; Diversity and inclusion; Performance and talent management; Engagement and rewards; Social dialogue; Protecting human and labour rights	-	7	56

Source: Compilation of the authors based on *Sustainability Reports* published by companies included in the sample, on their website



## Proper HR Audit and Due Diligence Process: Key Factors in a Successful Acquisition

Michal Pohludka<sup>a</sup>, Hana Štverková<sup>b\*</sup>, Aleš Panna<sup>a</sup>

<sup>a</sup>ZKV Career s.r.o., „, Chomutovska 38/10, 161 00 Praha, Czech Republic

<sup>b</sup>Department of Business Administration, Faculty of Economics, VSB – Technical University of Ostrava, 17. listopadu 15/2172, 708 33 Ostrava, Czech Republic

---

### Abstract

As a result of digitalisation and technological development, the nature of markets is changing, and companies are using every innovative activity and operation to maintain their positions. Some companies channel their profits back to research and development. Others appreciate the potential of acquisition activities. They invest in them as they realise the potential of the immediate positive synergy effects of these activities. This article examines the complex acquisition process from the buyer's point of view. The authors focused on the due diligence process and the necessity of performing an HR audit as part of the acquisition activities. The HR audit is regarded as the key process in acquisition mainly in the case of SMEs. The authors used a specific horizontal acquisition process to describe corporate cultures and harmonisation processes in an international environment. Cultural integration is usually one of the main reasons for failure of the acquisition process. All the steps described are critical to the successful operation of a newly emerging organisation.

*Keywords:* Acquisition; corporate culture; Due Diligence; HR audit; potential; processes;

---

### 1. Introduction

In the last few years, there has been a great deal of discussion about the fourth industrial revolution, which will have as part of its scope an impact both on industry and the economy, while also causing social changes. The objective of each company is long-term growth and the growth of its value, a significant position on the market and a powerful brand. However, as technologies develop and digitalisation and globalisation consolidate their place in business, the nature of markets alters. All these changes epitomise the phenomenon of Industry 4.0. Companies are using all the innovative tools available for their sales and marketing activities and set their operations while considering both geographic and product growth. Global companies are currently operating on almost all markets worldwide and are competing with other global players as well as with smaller local regional companies or start-ups.

An impact of globalisation and technological developments is an intensification of the competitive environment. Furthermore, this intensification complicates any adequate response to it. The frequency of the emergence of new companies, or rather new competitors on the market and of new products and technologies, has an exponential tendency, thus exerting significant pressure on large companies at any scale – local, regional or global. They in turn try to keep or reinforce their positions by creating their unique solutions, so they channel a high portion of profits back to internal research and development. The effects of these efforts have been very limited in the last decade as development and research initiated in reaction to the market events has enormous time limitations. That is why leaders in their segments, who dictate technological progress, mainly support their own development and research to a significant extent, and all other companies direct their other resources to acquisition activities, rather than to the costly development of new products.

Companies realise that investments in acquisition activities may have an immediate effect, and the companies may advance technologically, or even advance to other segments, thus diversifying their products or scope of operations, while also eliminating threats, such as during financial crises. Another advantage of acquisition activities is the mitigation of competition and the obtainment of competitive advantages in relation to other market players. In terms of acquisition, the current situation is characterised by two basic strategic cases – buying companies for the purpose of increasing market share or buying up small start-ups with exceptional ideas, technologies or solutions with enormous



potential. In such a case, big players are willing to buy such start-ups even if there is a high level of insecurity about whether the solution under development may be ultimately capitalised on the market, or not. The reason is the high level of competition, resulting in fear that the start-up might be bought by a competitor, and also a desire to grow at a low investment cost, compared to the company turnover. A current example may be the pharma segment, with quite a limited number of large players and a lot of small start-ups which are often formed with the aim of being sold.

Acquisition as such can be described as a process of one company acquiring or the buying another. The whole process, including the pre-acquisition stage, is very sensitive. In most cases, negotiations are held behind closed door and any leaks of information can make employees and business partners feel insecure. If the companies' shares are traded on financial markets, the value of shares would change significantly. In some cases, the offer for sale is public and often demonstrative, just to cause the said effects.

As the acquisition process period is quite short, it has its clearly set and defined steps to eliminate risks on both sides. In large-scale transactions, the process is managed by external companies who set the recommended price, level of risks and other important information for both buyers and sellers. The aim of the article is to describe this complex process from the buyer's perspective and to emphasise the importance of the process and of performing all of its stages. One part of the acquisition process is only rarely used and described – the HR audit. In this respect, we would like to point out in this article the importance of including this part into the standard due diligence process as a key factor of successful acquisition.

## **2. Acquisition process**

The whole acquisition process will be described from the buyer's perspective. The reason for this is to highlight the strategic management of a company which has the objective of implementing its visions and objectives through acquisition activities.

The acquisition process is clearly defined and may be divided into three essential stages by Sherman, 2010, and Gaughan, 2017:

1. Strategic analysis and finding an acquisition target
2. The negotiation and due diligence process
3. Integration of a company followed by an audit

The first stage is mostly performed internally in the company. Finding the right acquisition should be in line with the company's long-term vision and objectives, so the top management of a company is mainly involved in this stage, e.g. Soltes et al., 2015. Whatever the object might be, e.g. the consolidation of market positions, portfolio diversification, elimination of the competitors etc., the decision is made based on management consensus and appointment of an executive acquisition team, with all required competencies and responsibilities.

Other parties then become involved in the negotiation process with the purchased company. Here, the authors will focus mainly on global companies or large-scale acquisitions as they make up most of the acquisitions in terms of investments and their process is unified. Besides the company's executive team, advisors and the external company who manage the due diligence process also come into play, see Dvoracek et al., 2014. The extent of due diligence is optional. It is possible to either check only the basic areas of interest to the buyer or to make an extensive in-depth check. It depends on the buyer's particular requirements and the size of the sold/purchased company. These requirements are usually set in the beginning; however, they may change in the process depending on the findings made.

In this respect, due diligence can be described as a series of steps characterising the purchased company in three main areas – financial, legal and operational. Although the due diligence process is divided into three main areas, remember that it is a complex process providing the buyer with a complex characterisation of the purchased company. Following the due diligence process, either the price is verified, or a new price is set. It is also the basis for the subsequent integration and other steps. Before the process, a non-disclosure agreement is signed, and the terms of cooperation are set. The result of this process is a report available to the buyer and, in some cases, to the seller as well, e.g. Ernst and Young, 1994, and Dvoracek et al., 2014.

Financial due diligence is agreed between the buyer and the seller in advance, and it is focused on the accounting and economic aspects of the company that the investor is considering buying. It does not concern only the buyer, and the seller should not approach it lightly. Experience shows that it may confirm the asking price as realistic to both parties or indicate another real price and all potential risks in the process of sale preparations. The most significant threats are according to Dvoracek et al., 2014:

- No records of (potential) payables (such as from a court dispute)
- Non-rotation stock
- Tax optimisation
- Non-compliance with legal obligations
- Dependence of the target company on one (or only a few) customer(s)
- Bad debts of high value etc.

In the case of smaller companies, data concerning the companies' real operations must be considered. As part of tax optimisation, accounting operations are performed to reduce the company's real profits, thus reducing tax payments. In most cases, such operations are one-off expenses and should be excluded from the calculations of profit/loss. Then, it is possible to determine the real value of the company. This part of due diligence uncovering the real profit/loss is absolutely essential for both parties, more in Gleich et al., 2012, and Howson, 2012. The buyer has a real idea of the purchased company and may then plan the integration and progress of the whole company. The seller, on the other hand, has the value of the company raised by increasing the economic parameters including EBITDA.

In terms of a financial audit, the assessment of working capital is an indispensable part of due diligence. The appreciation of the working capital is different than in the operational part. The efforts here are to quantify it as part of the purchase price. Working capital means the difference between operating current assets and operating short-term liabilities. But this is just the theory. In practice, opinions on which item should be included in and excluded from the calculation differ widely. (In most cases, account details must be considered.) It should be the main subject of agreement between the buyer and the seller. The acquisition price is often agreed on a cash-free, debt-free basis. In such case, all financial funds and credit lines are excluded from the working capital, e.g. Gleich et al., 2012, and Howson, 2012, and Dvoracek et al, 2014.

It is worth noting that the efficiency of working capital management can draw the line between a successful company and a dying business.

Legal due diligence must always be performed from the lawyer's perspective. A lawyer should especially review all agreements the company entered into and check whether they are correct and of significance to the prepared acquisition. In addition, all available registers or shareholder links and participations in subsidiaries are checked. In this case, too, it is important to note relevant issues where the lawyer may have a different opinion than management. The lawyer's task is to point out these issues. The final decision, however, is management's responsibility.

During the operational part of due diligence, the company's operational data are collected, including, but not limited to, the list of suppliers, customers, production parameters, HR operations, etc. These data and evaluations are quite accurate and easy to characterise, except for the HR audit. In a large number of acquisitions, it is not performed at all. The significance of its absence is diminished with the size of the purchased company; however, it is absolutely fundamental for smaller acquisitions. In family-type companies or companies with a lower number of employees, dependency on individuals and individual teams is above all high. An HR audit may reveal the level of dependency and potential risks from losing such employees after acquisition. This information is so fundamental that in some cases, acquisition is subject to various competitiveness clauses, the prohibition on the executive team leaving the company, etc. The level of dependency and potential threats also changes the price of the company. When acquiring large or global companies, the HR audit loses significance as these companies are process-managed and the influence of individuals on the operation of the whole company is eliminated, more in Rao, 2014, and Nelson, 2015.

All the areas described above must be regarded as part of a complex. In other words, one threat (a shortcoming) may and does have an impact on other areas. For example, long-term overdue payables have a negative impact on cash flow. In terms of taxes, the company may become obliged to tax the payables in arrears. That is why in financial audits, cooperation with experts and advisors from other areas, e.g. taxation, law etc. working on the particulars of due diligence is frequent. Only in that case, will the buyer get complete information required for correct decision-making in negotiations.

If we take a closer look at the HR audit, each purchasing company tries to understand and describe each aspect of human resources of the purchased company. It includes a description of the following company parameters – organisational structure, competencies in individual positions, decision-making matrix, substitutability and dependency on individuals. An integral part is the identification of key employees and key positions and, last but not least, characteristics of its corporate culture. It is based on the above-described parameters and also defined by the management style and the style of communication regarding requirements and expectations. We can say that the corporate culture is unique in each company. Any change happens over a long period of time and with difficulty; it depends on the company management and its vision.

In the company integration process, the harmonisation of corporate cultures and processes and the centralisation of individual company sections are fundamental for the successful formation of a new merger, see Litavcova et al., 2017, and Hurta et al., 2017. Process unification depends on the centralisation of individual components, meaning most of all on human resources. As the whole integration process is managed in the change management system, the harmonisation of corporate cultures, branches and the selection of the right people is the initial element of success. And this important element will be described on a real example of acquisition harmonisation.

### 3. Corporate culture formation process as a part of acquisition

The horizontal acquisition process is explained by an example of a company operating in group C, the processing industry, group 11 production of beverages, based on the CZ-NACE classification of economic activities. Based on the decision of the company management and strategic analysis, a foreign holding (purchased company) was selected and an initial agreement on the merger of the companies was entered into with that holding. The strategic objective was to use significant cost and income synergies which will be attained by the companies' merger, thus intensively developing trademarks in a global scope.

An analysis of objectives, visions and individual elements indicated that the corporate cultures in the companies in question were very different. Visions and objectives were identical; however, the communication among managers of individual companies seemed problematic, complicating the acquisition process. Therefore, one of the partial objectives was to harmonise corporate cultures, implementing corporate culture into the daughter company.

Based on the findings of the horizontal acquisition of its foreign businesses, Figure 1 illustrates the specific procedure of formation of a new corporate culture.

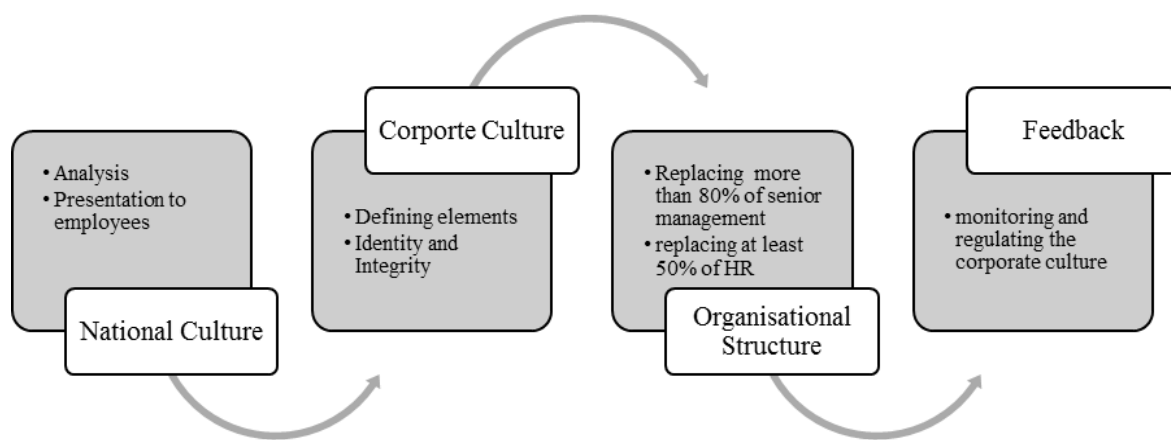


Fig. 1. Corporate culture formation process

The basic step for corporate culture formation was the analysis and comparison of national cultures. The results were then presented to employees, including the planned changes. Corporate culture was determined by defining the pivotal elements which will lead to the harmonisation of employees with the vision, objectives and strategy of the organisation and to integrity.

Another step, which proved to be the most time-demanding, was the formation of a new organisational structure. First, it was necessary to purchase all shares of managers in the company and then, it was possible to make extensive personal changes in senior management. By replacing more than 80% of senior management in the purchased company, it was possible to harmonise corporate cultures and begin the change process in the operation area, too. As senior management replacement was only the first stage of personal changes, in the second stage, 50% of human resources at lower positions were replaced as well. The reason was the employees' unwillingness to accept changes and the new corporate culture, including the new company management.

After introducing all the personal and process changes, the company takeover reached the final stage – monitoring and continuous supervision over introduced changes, with the efforts to improve them and react to the situations at hand immediately.

In the case outlined above, the whole process took 17 months. Frequent and transparent communication with employees and the identification of problematic individuals in the purchased company proved important for the whole process. Their attitude had a negative impact on individuals who were willing to believe in the new corporate culture and who were proactively assisting the management with its introduction. These negative and problematic individuals were replaced, and this step ultimately proved essential for speeding up the companies' integration, not only for the harmonisation of corporate cultures.

#### 4. Conclusion

We can say that acquisition activities are changing the situation on the market. To illustrate, based on Mergermarket, 2017, the global value of the mergers and acquisitions market is estimated at USD 3.15 trillion, with 18,433 transactions implemented in 2017. Compared to 2016, there was a slight drop, from USD 3.26 trillion. 2017 was the fourth year in a row where the value of transactions exceeded USD 3 trillion. The largest transaction was Disney's acquisition of Fox at USD 68.4 billion.

The whole acquisition process has a similar character across segments and individual differences may be seen in each part of the process. The most distinct and specific part is the above-discussed HR audit as part of due diligence and the HR area as part of companies' integration.

The complexity of acquisitions dictates the necessity of using external companies which have experience and a range of experts in various fields available. Only a limited number of these companies exist, and they are mainly global businesses. This allows for the sharing of information, experience, processes and experts across countries and continents, thus setting global standards in almost every country. From this perspective, the countries of Central and Eastern Europe are attractive for investors. They see huge potential in the companies operating in this region. Also, thanks to the global standard of the acquisition process managed by an external multinational company, they perceive such investment as safe. If we look at acquisitions in the Czech Republic, there were 246 transactions at almost USD 12 billion, which means 16% growth in transactions value compared to 2016. In this respect, it is important to note that the Czech Republic has been one of the leading countries of Central and South-East Europe in the number of transactions for several years now, more in Ernst and Young, 2017.

The contrast between the stagnating acquisition development on the global market and two-digit growth of acquisitions in the Czech Republic is proof of the appeal of Central and Eastern Europe. A similar trend is expected to continue. The above-mentioned example of an acquisition mainly emphasises the HR and financial area of the due diligence process and the companies' integration. They are fundamental to a successful acquisition.

As HR operations are a huge risk for the whole process and, sometimes, an unknown intangible quality, they should be one of the relevant areas. But in reality, they are not. It is one of the main reasons for the failure of a large percentage of acquisitions whose outcomes lag far behind the expectations.

Eighty-seven per cent of organisations report that the harmony of corporate cultures was important or absolutely necessary for a successful acquisition. The broad conception of corporate culture including the corporate strategy, decision-making processes and corporate management, top management's expectations and organisation values and standards are all important aspects in acquisitions. Nevertheless, 58% companies report that they were not specifically concerned about the issue of culture. Moreover, none of the surveyed companies reported that the cultural process in their organisation had been effective. According to Elizabeth Fealy responsible for Merger and Acquisition Solutions in Aon Hewitt, 2018 in the U.S., "This is very telling. The bottom-line is that, while organisations understand cultural integration is critical to deal success, they continue to struggle to implement processes that drive cultural integration forward."

What element has the largest share in the success of corporate culture and thus in the success of the acquisition process? Based on content and secondary analysis, the authors ranked these elements in the following order: Values, Attitudes, Standards of Behaviour, Fundamental Beliefs, Corporate Architecture, Habits, Rituals and Ceremonies, Organisational Language.

#### References

- Aon Hewitt. *Odlišné firemní kultury dělají z fúzí a akvizic velice riskantní záležitost*, <https://www.hrnews.cz/lidske-zdroje/rizeni-id-2698710/odlisne-firemni-kultury-delaji-z-fuzi-a-akvizic-velice-riska-id-1429152>, (2018).
- Dvoracek, J., Boukal, P., Klečka, J., Mika, P. *Due diligence - podstata, postupy, použití*, Wolters Kluwer, (2014).
- Ernst and Young. *Mergers and Acquisiton*. 2nd edition, Wiley, (1994).
- Ernst and Young. *M&A Barometr H1 2017 Česká republika*, EYGM Limited, (2017).
- Gaughan, P.A. *Mergers, Acquisitions, and Corporate Restructurings*, 7th edition, John Wiley & Sons, (2017).
- Gleich, R., Hasselbach, T., Kierans, G. *Value in Due Diligence: Contemporary Strategies for Merger and Acquisition Success*, revised edition, Gower Publishing, (2012).
- Howson, P. *Commercial Due Diligence: The Key to Understanding Value in an Acquisition*, revised edition, Gower Publishing, (2012).
- Hurta, H., Jazouli, A., Kopyay, T., Motaghi, H. Mergers and Acquisitions from the perspective of project management, *Polish Journal of Management Studies*, Vol. 15, Iss. 2, pp. 100-114, (2017).

- Litavcova, E., Heckova, J., Chapcakova, A. Cross-border mergers and acquisitions as efficient managent tool of capital allocation within European area, *Polish Journal of Management Studies*, Vol. 16, Iss. 1, pp. 94-104, (2017).
- Mergermarket. *Mergermarket Releases 2017 Full Year Global M&A Trend Report*, An Acuris Company, (2017).
- Nelson, V. *How to Conduct a Human Resources Audit and Protect Your Company*, Lulu Press, (2015).
- Rao, T.V. *HRD Audit: Evaluating the Human Resource Function for Business Improvement*, 2nd edition, SAGE Publishing India, (2014).
- Sherman, A. *Mergers and Acquisitions from A to Z*, revised edition, McGraw-Hill Professional, (2010).
- Soltes, V., Gavurova, B. Modification of performance measurement system in the intentions of globalization trends, *Polish Journal of Management Studies*, Vol. 11, Iss. 2, pp. 160-170, (2015).

# The Quality of Lending the Economy

Gabriela Corina Slusariuc \*

*University of Petrosani, 20 Universitatii str, Petrosani 332006, Hunedoara County*

---

## Abstract

Credit has a very important role in the economy, and the evolution of national economies has become largely dependent on the private banking system. Credit policy has become one of the main means of action on the economic conjuncture, being called upon to prevent the uncorrelations and potential imbalances that may arise. Poor credit risk management can cause the banking system to collapse, with unimaginable economic, social and political consequences.

*Keywords* : quality; loans; economy; credit; banks; companies; development

---

## 1. Economic growth is the goal of any state or company

Specialist papers (Lombardi et al., 2017) point out that economic growth is strongly influenced by debt levels. So the evolution of indebtedness generates a series of nonlinear effects. Measures to stimulate short-term lending have positive effects on the economic sector, but in the long run, the growth of private sector indebtedness leads to negative economic externalities.

Some authors (Schularick and Taylor, 2012, Jordà et al., 2013, 2015 and 2016) have pointed out that increased levels of private sector indebtedness are good predictors of financial crises and determinants of the intensity of implicit recessions. Other studies (Mian et al., 2015) mention that in times of contraction, households with high levels of indebtedness are most affected by the occurrence of adverse shocks.

His approaches (Cecchetti and Kharroubi, 2015 or Borio et al., 2016) based on the effects of debt on the supply sector demonstrate that excessive credit growth periods have long-term adverse effects on productivity through inefficient allocation of funds.

The EU financial system is very dependent on the banking system, with a significant impact on economic growth. The EU banking system has reached a level of magnitude that will have a negative impact on economic growth, leading to additional risks at both bank and sector level as a whole. Since the 1990s, banking intermediation has accelerated its pace of growth, with the share of credit in GDP in Europe increasing significantly compared with other regions of the world (US).

The size of the European banking sector is considered to be oversized in relation to GDP, as compared to the income and wealth of the population, as well as to other sources of intermediation. Large-scale universal banks have a higher systemic risk than smaller specialized activity banks, and they have a major share of total banks in recent years at EU level.

The main challenges facing the European banking sector are:

- increasing concentration within it,
- increasing the size within it,
- higher degree of indebtedness of European banks.

The ESR Advisory Scientific Committee (ASC) report shows that in countries with a financial system dominated by banks, there are lower increases in the long run, even after being controlled for other specific factors. The bank lending offer is more volatile than other sources of funding such as the capital market, amplifying financial and economic instability.

---

\* Corresponding author. Tel.: +0-000-000-0000 ; fax: +0-000-000-0000 .  
E-mail address: ellaslusariuc@gmail.com.

An economy that is mostly funded through the banking sector has contingent liabilities larger than an economy that is mostly funded through the stock market.

Thus, in bankruptcy of banks, the state is always the ultimate lender to cover possible system losses, even though this risk has diminished with the emergence of the bail procedure and the bank resolution framework. By contrast, a stock crash does not present contingent liabilities for the state, in which case the risk is entirely assumed and borne by the investors on the stock exchange.

In this context, the main policy measures that have been proposed to be adopted at European level are:

- 1) the elimination of preferential tax treatment of debts;
- 2) adopting more aggressive competition policies to diminish the importance of large banks;
- 3) increase in minimum capital requirements (either by setting a minimum leverage ratio or by setting up a capital buffer for systemic risk) in order to increase the resilience of banks and protect taxpayers from the potential risks generated by an over-sized banking system;
- 4) policies that encourage access to non-bank credit sources;
- 5) the formulation of requirements for the separation of certain non-banking activities from the core business of banks
- 6) increasing the risk weights associated with the existent intra-financial exposures, in order to reduce the excessive activities within this sector (as stipulated in CRD).

Romania, in the first years of the post-communist period, has witnessed a strong financial disintermediation process, the share of credit to the private sector in GDP falling from 79.7% in 1990 (a characteristic of the planned centralized economy) to only 19.1% one hundred in 1994.

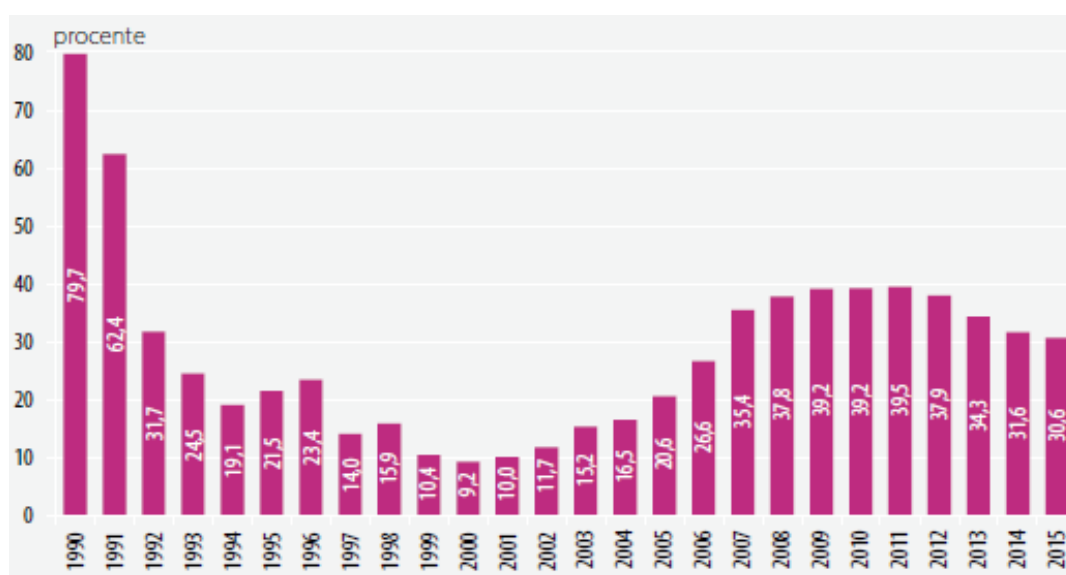


Fig. 1. Credit to the private sector / GDP in Romania. Source: EBA, NBR

High inflation recorded since 1990 has led to the limitation of credit. The very high inflation rates (in 1992 and 1993 close to hyperinflation) and their high volatility drastically limited the possibility of financing medium- and long-term projects (Isărescu, 2007). Also, the negative interest rates led to the rapid erosion of the population's economies and banks' reluctance to lend to the population.

Banks have faced the problem of not having a profitable client for lending because there was no portfolio of creditworthy firms, state-owned companies were in cumbersome privatization processes, and private ones were poorly developed.

Against the backdrop of financial indiscipline, they replaced bank credit with arrears - which reached about 85% of GDP in 1991.

The location of financial intermediation on a low level after 1990 was also determined by the very modest level of credit for the population, its share in credit to the private sector being up to 6 percent, almost exclusively focusing on companies.

The period 1995-1996 was characterized by an increase in targeted credit, but with negative effects in the economy.

Thus, the banking system soon faced a very high level of bad loans, but also a severe deterioration in corporate governance, and rescue from bank failures had a budget cost between 4.6% and 6.6%. After 2000, private sector lending was on an upward trend, supported by economic growth, inflation and interest rate cuts, as well as the presence of foreign banks in the domestic banking system, which strengthened.

The real annual growth rate of credit to the private sector recorded negative values in the period 2012-2014, returning positively from 2015. This year, the RON component became dominant in the credit structure after a period of 8 years in which the foreign currency credit held the majority position.



The credit for the population became a more dynamic component in 2016, being predominant in the structure of the loan stock. Sustainable lending to non-financial corporations is a priority of the Romanian banking system, as many SMEs are not eligible for credit, and many corporations resort to intragroup loans.

## 2. Credit to companies and the population

Sustainable growth of financial intermediation, particularly by widening the lending sphere to the corporate sector, remains a desideratum for the banking sector.

Between September 2016 and September 2017, the volume of new loans granted by credit institutions amounted to about 42 billion lei, representing a credit growth rate of 18.5 percent. The new flows of loans to non-financial corporations recorded a more rapid dynamics than those of the population (8% increase in the first case, compared to 6% in the second, in nominal terms), while in the case of loans granted to the sector of the population, an important part (about 31 percent) was achieved through the "First House" program.

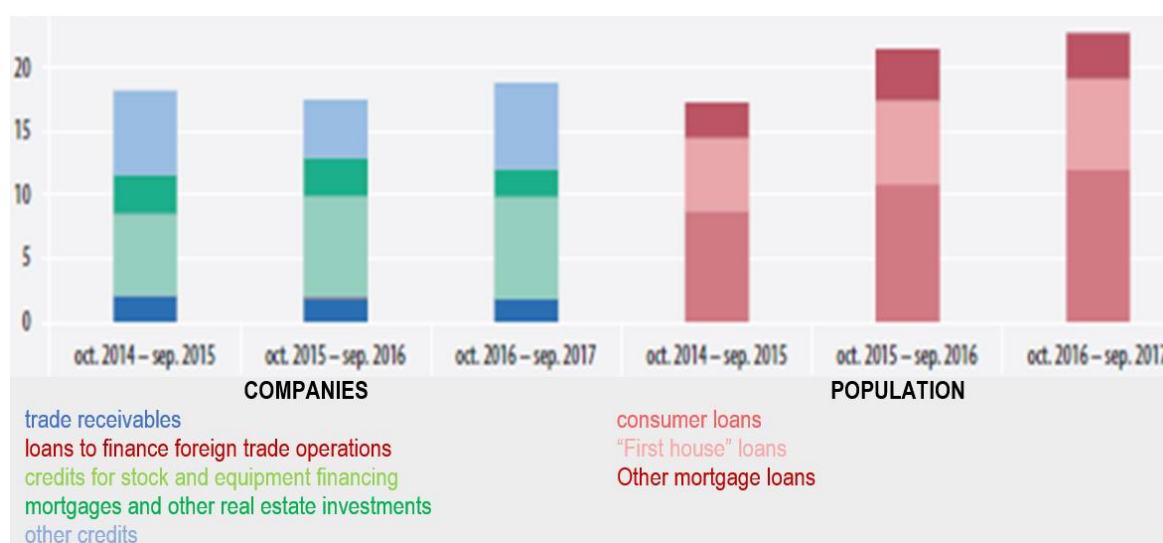


Fig. 2 Structure of the new loan granted. Source: EBA, NBR

Individual borrowers who accessed loans in the years 2015 and 2016 have a moderate but pro-risky risk profile. The indebtedness of borrowers who have accessed new loans has been in recent years on an upward trend beginning in 2013-2014, as revenue has seen a positive trend in recent years.

Thus, debtors who currently have bad debts have a very high degree of indebtedness (47 percent, compared with 33% for people with high-performing exposures) and a significant share of them is remunerated with a salary below the average at national level (about 80% of them).

Maintaining an adequate degree of prudence, even if it can reduce the access to credit for low-income and very low-income people (below the minimum wage), provides additional protection to eligible borrowers in the event of shocks, especially for those who will contract mortgages, which are particularly vulnerable to interest rate shocks. Slight developments in bank financing are due to structural features such as demand and supply. The main elements limiting the solvable credit claim are represented by:

- the high degree of indebtedness of certain categories of companies, especially micro-enterprises;
- the high number of companies with negative or non-performing equity;
- deficiencies in the insolvency framework of legal persons.

The credit offer raises issues related to the training of bank staff, the provision of financing products that do not address the specific problems of non-financial companies and the preponderance of real estate collateral.

The demand for bank lending by the non-financial corporations sector is low, with other sources of financing being used, such as commercial credit, loans from shareholders or affiliated entities, respectively from non-resident financial institutions. In the period 2004-2017 no more than 15% of the economically active companies have used such loans.

## 3. Bad credit against banking institutions

The quality of the portfolio of loans to non-financial corporations continued to grow, dynamics being mainly influenced by the aggregate improvement of the financial situation of firms. However, the constraints generated by the existence of structural vulnerabilities, such as the undercapitalization of a significant number of companies, the high degree of indebtedness in certain sectors, the reduced capacity to recover commercial claims, especially at micro-

enterprises, combined with the large number of firms of the portfolio of credit institutions that have not gone through a complete business cycle are risk factors for the banking sector.

The rate of non-performing loans decreased by 4 percentage points between September 2016 and September 2017, reaching a value of 15.8 percent. The annual change in the rate of non-performing contributed both to the decrease in the volume of loans with a higher payment delay 90 days (by 0.7 percentage points), as well as the reduction of loans in the implausibility of payment (by 2.3 percentage points).

The average default rate for Romanian companies fell to 3.1 in September 2017, from the 3.9% recorded in September 2016, as the number of companies that entered the default for the first in the last 12 months continued to remain on a declining trend.

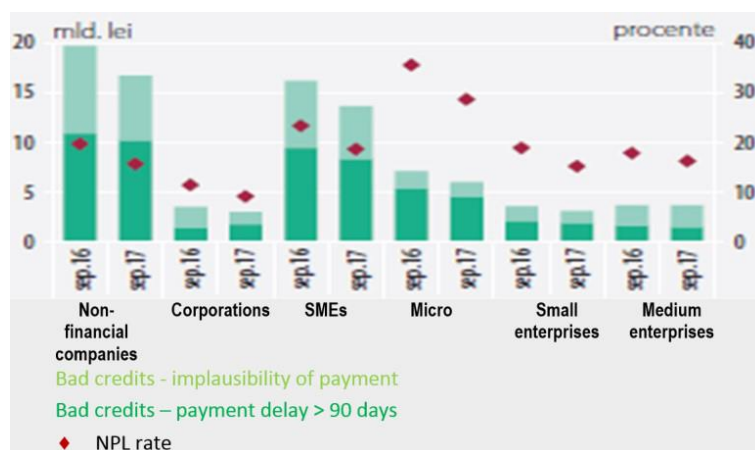


Fig. 3. Rate of non-performing loans according to the size of the companies. Source: NBR, MFP

An important role in determining the evolution of the non-performance of the portfolio of loans granted to companies by banks is provided by firms with a capitalization below the regulated threshold. They accumulate late payment loans for more than 90 days, of about ROL 5.6 billion in September 2017, accounting for 55% of total exposures of this type.

If are taken into account the credits that are unlikely to payment, the loans classified as non-performing by the undercapitalised firms amount to lei 7.7 billion, or 46% of the total non-performing loans generated by the companies sector in banks' balances.

Given the relatively high exposure of banks to companies with capital values below the regulated limit but not yet in default (about 13% in September 2017), the fragile financial situation of this category of companies may put pressure on the balance sheets of credit institutions over the next period. Another important factor that may lead to an increase in the default rate on loans is the high proportion of newly-granted variable-rate loans under the resumption of the cycle of interest rate hike due to rising inflation. Most companies would quickly feel a potential shock on the interest rate.

New loans are granted mainly with variable interest rate, 88% of the new loans granted in MDL, respectively 85% of those granted in euro have the variable interest rate.

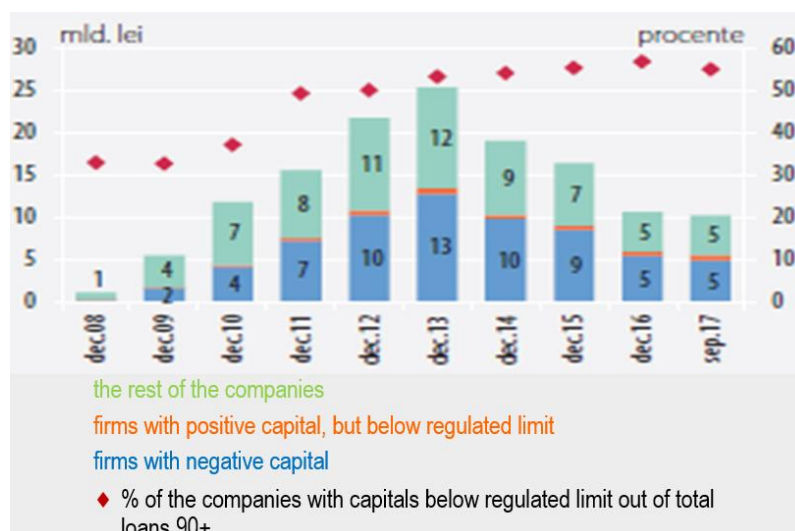


Fig. 4. Loans with overdue payments of more than 90 days, according to the capitalization of companies. Source: EBA, NBR

Companies with the highest risk profile are micro-enterprises, with a non-performing loan rate of 28.8% in September 2017. However, both small and medium enterprises and corporations recorded credit risk mitigation between September 2016 and September 2017. In the case of SMEs, the rate of non-performing loans fell from 23.4% to 18.7 percent, while for corporations it was 9.2% in September 2017, from 11.5% in 2016.

The rate of non-performing loans still places the Romanian banking sector, together with many other EU countries, in the red signal band of the Risk Chart developed by the European Banking Authority, but, as a counterweight, the coverage ratio with non-performing loans is at an adequate level and growing.

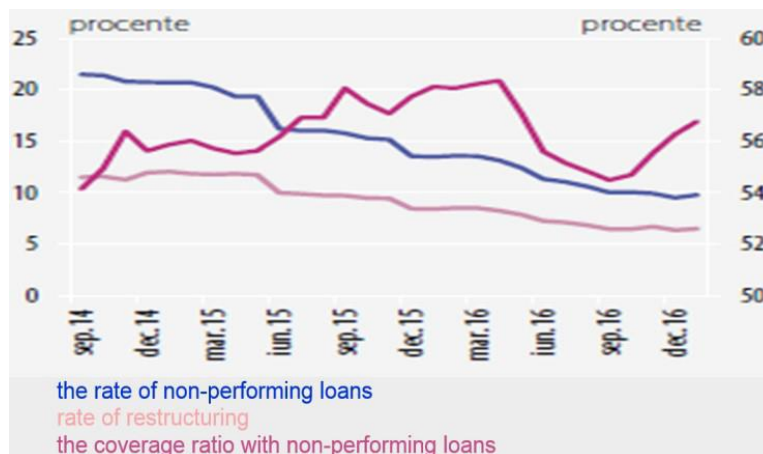


Fig. 5. Evolution of asset quality indicators in Romania (EBA definition). Source: NBR

#### 4. Reducing bad loans is a priority both in Romania and at European level

Romania has witnessed a significant increase in the non-performing loans rate since the financial crisis of 2008. The main result of the NBR's supervisory and regulatory measures as well as banks' balance-of-payments efforts was to reduce the non-performing loans ratio to a level 9.8% in January 2017 (in September 2014, the rate of non-performance was 21.5 percent, as defined by EBA). At the same time, these measures proved their effectiveness and generated one of the fastest reductions in the rate of non-performing loans among EU countries.

According to the EBA, a level of non-performing loans of over 8% of total credits (the case of Romania) is in the red band; a level of non-performing loans of 3-8% falls into the yellow band; a level of underperforming loans of less than 3% of total credits falls into the green band.

The Central and Eastern European countries, which are under the low red-tape credit rating, have a negative growth rate of credit (Croatia, Russia), or a weak pace similar to that of Romania and Bulgaria.

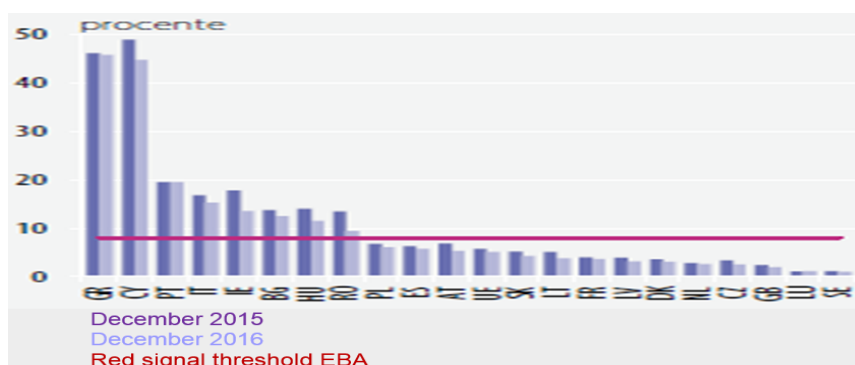


Fig. 6. The rate of non-performing loans in EU countries. Source: EBA, NBR

#### Conclusions

The rate of non-performing loans continues to remain high, despite the banks' efforts to reduce them, especially in certain business segments, which advocates continuing the process of solving exposures in state of non-reimbursement by credit institutions.

Macro-prudential regulations target the segment of lending to the population (especially foreign currency lending), but also the non-financial sector. The measures consist in establishing limits on the degree of indebtedness in relation to the amount of disposable income and the value of the collateral.

Thus, the role of credit needs to be repositioned, the new economic conjuncture requires changing the engine of economic growth with a more autonomous one, based more on productivity and domestic saving and less on capital influxes and indebtedness.

## References

- Apergis, N.,Filippidis, I., Economidou, C., *Financial Deepening and Economic Growth Linkages: A Panel Data Analysis*, Review of World Economics, vol. 143(1), pp. 179-198, (2007).
- Balgova, M.,Nies, M.,Plekhanov, A., *The Economic Impact of Reducing Non-Performing Loans*, Working Paper No. 193, BERD, (2016).
- Borio, C.,Lombardi, M., Zampolli, F., *Fiscal Sustainability and the Financial Cycle*, BRI Working Papers no. 552, (2016).
- Calderon, C.,Liu, L., *The Direction of Causality between Financial Development and Economic Growth*, Journal of Development Economics, 2003, vol. 72, issue 1, pp. 321-334, (2003).
- Isărescu, M., *Intermedierea financiară în România în perioada 1990-2007*, Universitatea George Bacovia, Bacău, august (2007).
- Köhler-Ulbrich, P.,Hempell, H. S., Scopel, S., *The Euro Area Bank Lending Survey. Role, Development and Use in Monetary Policy Preparation*, ECB Occasional Paper, no. 179, <http://www.ecb.europa.eu/pub/pdf/scpops/ecbop179.en.pdf>, (2016)
- Olteanu D.C., *Creditarea și instabilitatea economica*, Studii Economice, Academia Română, Institutul Național de Cercetări Economice, București, (2014)
- Rădulescu, E., Mihai, I., Popescu, R., *Analiză privind programul de creditare ipotecară cu support guvernamental «Prima casă»*, mimeo NBR, (2017)
- Rascolean I., Slusariuc G., Dobra R., Păsculescu D., *Graphical simulation program for credits portfolio quality analyze*, Proceedings of the 1st International Conference on Computational, Science and Engineering (CSE '13), Valencia, Spain; 08/2013, pp133-139, ISBN: 978-960-474-319-3, (2013)
- \*\*\**Guidance to Banks on Non-performing Loans*, 2017 [https://www.bankingsupervision.europa.eu/ecb/pub/pdf/guidance\\_on\\_npl.en.pdf?b2b48eefa9972f0ca983c8b164b859ac](https://www.bankingsupervision.europa.eu/ecb/pub/pdf/guidance_on_npl.en.pdf?b2b48eefa9972f0ca983c8b164b859ac)
- \*\*\**“The Italian NPL Market. Positive Vibes”*, decembrie (2016), <http://www.pwc.com/it/it/publications/npl-market.html>
- \*\*\**EBA Report on the Dynamics and Drivers of Non-performing Exposures on the EU Banking Sector*, iulie (2016), <http://www.eba.europa.eu/documents/10180/1360107/EBA+Report+on+NPLs.pdf>
- \*\*\*NBR *Sondaj privind accesul la finanțare al companiilor nefinanciare din România și capacitatea acestora de a face față unor condiții financiare nefavorabile*, decembrie (2016)
- <http://www.NBR.ro/PublicationDocuments.aspx?icid=15748>
- [www.NBR.ro/files/d/Pubs\\_ro/Caiete/2017cs48.pdf](http://www.NBR.ro/files/d/Pubs_ro/Caiete/2017cs48.pdf)
- [www.NBR.ro/files/d/Pubs\\_ro/RSF/RSF2017\\_2.pdf](http://www.NBR.ro/files/d/Pubs_ro/RSF/RSF2017_2.pdf)

## Digital Public Sector Auditing: a look into the future

Tatiana Antipova\*

*ICS Rusia, Rusia*

---

### Abstract

This paper considers future features for public sector auditing. Digital Public Sector auditing provides a window to view trends, issues, and relationships across a wider expanse of data, and provide more meaningful and insightful observations to Public Sector leaders and stakeholders for improving Public Sector performance. Auditor highlighted the top transformative changes of Public Sector Auditing and based on this changes builds a logical scheme of digitalization with look in the future. The use of digital technologies in Public Sector auditing will help to analyze the result of budgetary funds using of audittee, find ways to solve the problem of rational use of budget resources and optimize fiscal relations in each Public Sector unit. In author's opinion digitalization's framework consists of three blocks: Standardization, HR Management, Data Management. During future auditing procedures public sector auditors must use modern digital technologies; strengthen investigative powers; encourage more professional designation; support the international transparency. In addition, using day-to-day digital technologies is a perfect way to prevent any kind of fraud with budget money.

*Keywords:* Public Sector auditing system; Supreme audit institutions; control procedure; digitalization; digital technologies; digital auditing.

---

### 1. Introduction

Nowadays, with globalization of the economy, good governance of public finance is of fundamental importance for all countries to ensure the sustainability of the national budget and financial systems, as well as mutual financial security and sustainable economic growth. The public sector of many economies has been subject to dramatic change and auditing is a major mechanism by which many of these changes have been enacted. Effective budget implementation is an important factor in influencing the volume and quality of public services. Furthermore, it is important to bear in mind that leakage of resources through poor accounting directly threatens fiscal stability since it requires more resources than should be necessary to achieve any given result. Public Sector auditing provides independent assessments of that information for the benefit of those charged with oversight and for the public. When public are confident that the information they receive is relevant, reliable, understandable, consistent and comparable, it creates trust. Transparency and public accountability further engender trust in a representative democracy. Working together, these factors lead to greater citizen satisfaction and better access to capital at a lower cost. As long as budget resources come from the public in the form of taxes, every citizen demands greater understanding of where their tax money goes and how it is spent and control (Antipova, 2016). To understand this control mechanism it is necessary to know the structure of the Public Sector. The most common public sector comprises General Government and Public Corporations. Government-owned enterprises, such as the central bank, post office, or railroad are often referred to Public Corporations. General Government usually consists of three levels: Central Government, State or Regional Government, and Local Government. Public Corporations are divided on Nonfinancial (e.g. post office) and Financial (e.g. Central Bank).

Public Sector auditing focuses attention on how budget resources are spent. Assessment procedures of Public Sector auditing serve to avoid misrepresentation and fraud in public sector financial statements. Since the public sector financial statements are placed on the Internet, any citizen can get acquainted with this reporting. And citizens can trust the information set in these financial statements if auditors verify it properly. Public Sector Auditors should assess fair presentation of public sector financial statements. When financial statements “furnished by a state agency are in fact

---

\* Corresponding author. Tel.: +7-912-982-4618.  
E-mail address: antipovatianav@gmail.com.

reliable, citizens' trust should be increased by auditors. When, on the other hand the information is significantly unreliable, auditors should reveal that and consequently decrease citizens' trust" (Budding & Grossi, 2014).

Improving access to public sector information provides numerous benefits, particularly as increased transparency and efficiency within Public Sector (both state and local) can be quite advantageous. During audits, Supreme Audit Institutions (SAI)s often accumulate and process potentially useful information for various stakeholders, but this information is not readily accessible. To enhance information accessibility, these initial information files could be made public if they do not contain classified or personal information. Auditing every auditee would be daunting and resource intensive. However, it is important to spread audit findings and best possible. While press conferences, seminars and webinars present traditional channels for disseminating information, it is also possible to actively engage local Public Sectors in assessing their own situation (Antipova, 2017). We are in a "wired world" with information of all shapes and sizes available 24/7. All levels of Public Sector have substantially invested in modernizing information technology (IT) systems and service delivery models to take advantage of dramatic IT advances (Lewis et al., 2014) but the basic methodology for auditing hasn't changed significantly in decades (McCollum, 2017).

## **2. Public Sector Auditing digitalisation**

As point A. Lewis (Lewis et al, 2014), the benefits to modernizing the Public Sector audit approach for both the auditors and auditee are: enhanced effectiveness, additional business insights, greater efficiency, better detection of fraud, waste, and abuse. Public Sector Auditing digitalization advanced continuous monitoring and continuous auditing programs, expanded forensic and recovery auditing capabilities, and sophisticated data analytics and business intelligence efforts. A natural first step in implementing data-driven digital techniques is to determine to appropriate transactions in the context of an auditee's day-to-day life. Because these guidelines vary by agency and program, it is important for agency administrators and subject-matter experts to collectively brainstorm the common-sense ways that online operation may be used, as well as the ways they should not be used (Antipova, 2017).

To manage Public Sector auditing results we need to use of modern digital technologies but digital Public Sector auditing is not just a technology-based effort. It involves changing the expectations of what is included within an audit, and adjusting auditors' knowledge, skills and abilities (Lewis et al., 2014). This is especially true in terms of implementation of results-based budgeting, as well as openness and transparency in the sphere of Public Sector auditing (state financial control) (Antipova, 2016). The formation of an information portal in the field of Public Sector auditing will allow for the recording, monitoring and analysis of inefficiencies and take measures to optimize budget expenditures. The Internet portal will provide the opportunity to hold videoconferences, implement electronic document management, work with documents, create and use an electronic library, conduct training, store information of the Supreme Audit Institutions and other control and accounting agencies and implement other services. It would be great if the results of Public Sector auditing were taken into account when budgeting for the next period. In the future, it is possible to link the definition of the size of the budget subsidy to the results of the Public Sector auditing while ensuring the transparency of the results of control through digital information technologies and the standardization of Public Sector auditing. The use of digital technologies in Public Sector auditing will help to analyze the result of budgetary funds using of auditee, find ways to solve the problem of rational use of budget resources and optimize fiscal relations in Public Sector unit, see Fig 1.

As wrote Farr L. (Farr L., 2017), auditor highlighted the top five transformative changes that are driven by modern information technology (IT): 1. Governance complexities; 2. Cyber everything; 3. Full transparency; 4. Reporting on steroids; 5. Skill set shortages.

1. Governance complexities. In many organizations, cybersecurity is "owned" by the IT function, which is tasked to implement, supervise, and maintain new systems and applications. Today, cybersecurity must be owned by the entity itself, because the location, accuracy, and security of a company's data, and the resiliency of its network to withstand cyberattacks, represent a business and compliance issue of importance to senior executives and board members. Cybersecurity involves more than just technology networks and systems, given the people and processes that may inadvertently make an organization susceptible to a cyber-attack. Cross-collaboration across the enterprise is essential.

2. Cyber everything. Technology is embedded deeply across every company today, producing a fast-changing array of cybersecurity risks. "Cyber is in everything," Katcher said. "Although technology itself is becoming more secure, the weakest link remains people, followed by inferior processes for attack detection, system recovery, and crisis management." Here, there, and everywhere data. Every company has what IT professionals call its "crown jewels"—highly sensitive customer data such as credit card numbers or proprietary business information. Unfortunately, many businesses have not identified their crown jewels, much less who is allowed to access these data and on which types of devices. "If you don't know where the critical information is, how can you secure it?" Katcher said.

*According to B. Bebre (Bebre, 2018) there are three way to cibersecure: (a) data protection; (b) cybersecurity considerations; (c) staff training.*

*(a) designe to protect data. Examples of this work include reports on the National Cyber Security Program and Protecting Information Across Public Sector. Both reports document the difficulties involved in protecting information while redesigning public services and introducing necessary technology to support them.*

(b) cybersecurity considerations are increasingly featured in a wide range of projects and initiatives, from digital transport schemes to smart energy meters and secure online financial transactions. The NAO noted in its report on Online Fraud that the internet is changing the nature of crime, and law enforcement responses are struggling to keep up. As more and more public services are delivered online and internet connectivity is steadily becoming a feature of everything—from military equipment to medical technology—considering cyber elements is likely to become a bigger part of audit work.

(c) training staff to help auditors think about cyber issues they may face. Cybersecurity is a fast-paced area, and Supreme Audit Institutions should continue to learn about technical and policy developments. Spreading good practice and awareness can help auditors adapt. For example, during the annual training and development week, Public Sector and industry representatives, addressed Supreme Audit Institutions staff and provided them with the latest developments.

3. Full transparency. The transparency of cybersecurity risk management is important for the good governance of all business entities. Corporate leadership seeks transparency into business and market data to increase the speed of operational decision-making. And boards of directors expect accurate reporting on the security of the organizations they serve.

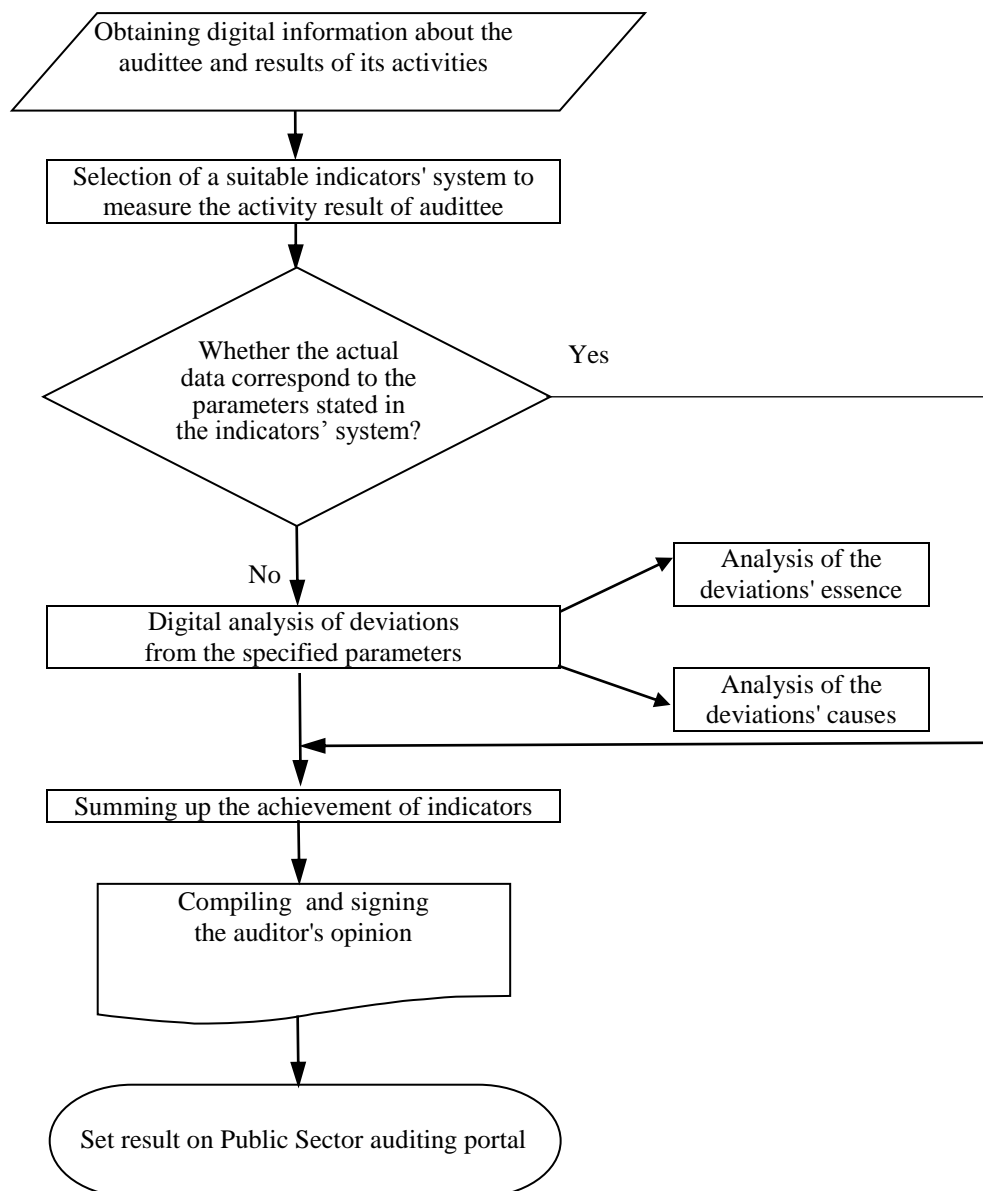


Fig. 1. Block-scheme for using digital technology in Public Sector auditing (author's elaboration).

4. Reporting on steroids. Reporting used to entail an analysis of the financials and the application of judgment. Today, accurate reporting depends upon how the data are input, processed, and stored, and the security risks presented in each scenario. "Simply stating information and reporting that the data is accurate no longer is enough," Katcher said. "CPA firms must provide evidence demonstrating that a client's data is complete, accurate, valid, and secure."



5. Skill set shortages. With technology increasingly driving how business is conducted, the tasks traditionally performed in the work environment are rapidly changing. Augmented intelligence, machine learning, robotics, and other transformative technologies are combining in unique ways to replace some jobs, augment others, and demand the development of new skills. The challenge for many organizations is the dearth of talent to fill these roles.

These transformative changes cause to Public Sector audit digitalization. And digitalization's framework consists of three blocks:

- A. *Standardization*
- B. *HR Management*
- C. *Data Management*

*A. Standardizations*

To unify verification procedure Blockchain Data must be standardized. Standardization can help to maximize compatibility, interoperability, safety, repeatability, or quality. It can also facilitate commoditization of formerly custom processes. The idea of standardization is close to the solution for a coordination problem, a situation in which all parties can realize mutual gains, but only by making mutually consistent decisions. In the context of supply chain management and materials management, standardization covers the process of specification and use of any item the company must buy in or make, allowable substitutions, and build or buy decisions.

*B. HR Management*

It is well known that "cadres decide everything." In the face of global competition can not continue to base education on the use of cheap labor. Principles of formation and staffing of personnel policy are determined by the new requirements of the Public Sector auditing body in terms of improving the quality of the training process and scientific research, its results and the reflection in Public Sector auditing. To achieve quality auditing, it is necessary to develop and effectively implement operations throughout the value chain organization, and this will require the development of knowledge, skills and abilities of auditors. It is advisable to develop a scheme for premium pay for auditing services, depending on their quality, meeting deadlines. There is no need for initiatives to award or the number of procedures performed. There should be rewarded for results. There is another issue in designing the reward - is the choice of the number of criteria. Indicators formulated in accordance with auditing strategy should be consistent with two or three strategic areas (such as more efficient use of assets).

In auditing, the priority is given to auditors, who can draw a general picture of the cause-and- effect relationships that unite the various factors to achieve results. Activated involvement in auditing activities related to the priority areas, increasing the number of scientists and adviser is changing the structure of the load in the direction of its greater focus on research.

The effectiveness of human resource management can also help and a clear allocation of responsibilities and accountability. In addition, the leadership of the Public Sector auditing body needs to keep track of the passage of the regular training of the teaching staff. It is also very important to include measures to reduce the potential for conflict of interest in the audittee environment. This is important for the creation of a positive atmosphere in the team with the approved policies and procedures. In addition, with a more educated and specialist workforce, Public Sector audit bodies are now taking on managerial and policy roles that previously may have been the domain of generalist civil servants. In turn, this gives Public Sector auditing work greater credibility and a more informed approach.

*C. Data Management*

Data Management means the need to implement it on all the major management activities: counting and regulating the number, registration, identification of management unit opportunities, planning, evaluation, promotion of affairs unit, etc. Managing of the connection base and works, is a traditional works management process, and should be carried out by the executors of these works.

### **3. Future of Public Sector auditing**

Over the past six years, the author has led the Public Sector auditing for more than 60 of Federal agencies/entities and private firms. Analyzing as a scientist the results of numerous audits' results, the author singled out the main directions on which it is desirable to develop Public Sector auditing.

Existing manuals/instructions of Public Sector auditing aimed at identifying violations after the fact, studying financial statements, when nothing can be corrected. Comply with current guidelines, Public Sector auditors/inspectors can only led follow-up control. Future technologies should be aimed at preventing the misuse/violation of budget spending, when it is possible to stop the suspicious transactions, using information obtained from scanning banking operations of the observed audittee.

Analising past practical experience, author reached to conclusion that trends in Public Sector auditing in the future may include four main blocks that have shown on Fig.2.

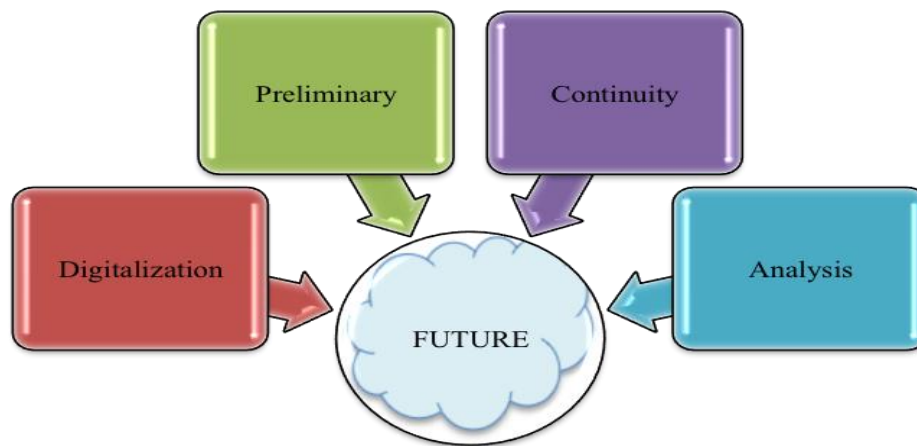


Fig. 2. Look in the future of Public Sector auditing (author's elaboration).

Fig.2 shows four main component of the future trend of Public Sector auditing: Digitalization; Preliminary; Continuity; Analysis.

**Digitalization.** Computerization has covered all aspects of our life and, naturally, this has not bypassed the scope of Public Sector auditing. Nowadays it is unthinkable to led auditing without using of modern digital technologies. For example, audits are more effective when auditors have online access to the movement of the funds of the inspected object on bank accounts opened with the Treasury bodies. Agencies looking for more out-of-the-box solutions might find audit-specific tools, referred to as computer-aided audit technology, more effective. The key for the future is learning to communicate and work virtually with auditee. Being familiar with this technology positions auditors/inspectors for the audit of the future. A digital audit turns the practice on its head: The work that's usually done in the field is done virtually in the office, and the wrapup phase, which is normally done in the office, is done in the field. Rather than traveling to auditee offices, the auditors perform the routine work of examining the client's documents in the auditors' office using information uploaded to a secure portal. Once the routine tasks are completed, engagement leaders visit the client for the wrapup phase. In the audit of the future, with artificial intelligence and analytics, many of these bindings will be executed virtually. For more details, see the previous section.

**Preliminary.** Public Sector auditors must ensure reasonable confidence in preventing or detecting suspicious acquisitions in a timely manner at the expense of budgetary funds. To enable predictive modeling, data sets must comprise transactions considered suspicious and the outcomes of investigations. Combining observations and their outcomes allows supervisors to begin to build the link needed to predict future occurrences of purchase misuse. While rule violations are not always indicative of misuse, they are an effective and simple way to alert program administrators to aberrant behavior. Whether a public sector transaction supervision system is automated or manual, supervisors should explore ways to integrate business rules and rule violations into the Public Sector audit process. Wherein an effective notification system operates over the Treasury central server, delivers event messaging to predefined employees in "real time," as the event occurs, and is sent directly to the employees and their smart devices. This level of event notification ensures that the people who need to know about an incident are made aware in a timely manner and fosters immediate and unified response as required (Antipova, 2017).

**Continuity.** Continuous auditing involves frequent monitoring throughout the year to ensure that transactions are captured properly and are flowing correctly to the income statement. During Digital Budgetary Transactions Surfing flows of transactions are continuously monitored, identifying transactions that match certain pre-determined integrity constraints and, in the event of a constrain violation, alert the Public Sector auditor and copy the transaction data to a file. A natural first step in implementing data-driven techniques is to determine to appropriate transactions in the context of an agency's day-to-day life. Digital audit techniques can be combined with this.

**Analysis.** Data analytics will be the foundation of Public Sector auditing in the future. Exploratory analysis and trending allow program administrators to identify patterns and detect anomalous behavior. Basic statistics like mean, standard deviation and skew, along with commonly accepted "tests," help identify transactions that are unusual. Such outliers and anomalies should raise red flags with supervisors and indicate the need for further investigation. Using existing technology, auditors examine a auditee transactions to spot trends. For example, a customer whose previous ontime payment suddenly slows to 10 days late may signal a risk of default.

If machine learning algorithms become too smart, can they be controlled? Domingos says there are ways to control machine learning algorithms, most notably by raising or lowering their ability to fit the data such as through limiting the amount of computation, using statistical significance tests, and penalizing the complexity of the model.

He says one big misconception about AI is that algorithms are smarter than they actually are. "Machine learning systems are not very smart when they are making important decisions," he says. Because they lack common sense, they can make mistakes that people can't make. And it's difficult to know from looking at the model where the potential for

error is. His solution is making algorithms more transparent and making them smarter. “The risk is not from malevolence. It’s from incompetence,” he says. “To reduce the risk from AI, what we need to do is make the computer smarter. The big risk is dumb computers doing dumb things.” (McCollum, 2017)

#### 4. Conclusions

Introducing new approaches and techniques in Public Sector auditing has been a challenging yet immensely rewarding process. By improving the impact of audits, Public Sector audit Institutions’ can steadily move closer to better public governance. Embracing digital Public Sector auditing is a necessary investment to move auditors to new and evolving techniques that modernize Public Sector auditing by making gull use of current and emerging technologies. We are in an information age and the exponential growth of data brings both challenges and opportunities to overhaul traditional sampling-based auditing approaches and fully leverage technology (Lewis et al, 2014). Digital Public Sector auditing provides a window to view trends, issues, and relationships across a wider expanse of data, and provide more meaningful and insightful observations to Public Sector leaders and stakeholders for improving Public Sector performance. During future auditing procedures public sector auditors must use modern digital technologies; strengthen investigative powers; encourage more professional designation; support the international transparency. In addition, using day-to-day digital technologies is a perfect way to prevent any kind of fraud with budget money.

In Public Sector auditing digitalization we will enable Public Sector auditors’ professionalism to move into the future and add even greater value to managing the cost of Public Sector and providing the highest levels of accountability and transparency to the civil public.

#### References

- Antipova T., Public Sector Auditing Systems in Indonesia and Russia. In: Antipova T., Rocha Á. (eds) Information Technology Science. MOSITS 2017. Advances in Intelligent Systems and Computing, vol 724. pp. 159 – 166. Springer, Cham, (2018).
- Antipova T., Fraud prevention by Public Sector auditors. 12th Iberian Conference on Information Systems and Technologies (CISTI). pp. 1 - 6, DOI: 10.23919/CISTI.2017.7976024, (2017).
- Antipova, T., Auditing for Financial Reporting. In: Global Encyclopedia of Public Administration, Public Policy, and Governance. Springer. Switzerland. 2016. [http://link.springer.com/referenceworkentry/10.1007/978-3-319-31816-5\\_2304-1](http://link.springer.com/referenceworkentry/10.1007/978-3-319-31816-5_2304-1), (2016).
- Bebre B., Using innovative tools and techniques in local Public Sector auditing. *International Journal Of Public Sector Auditing* [serial online]. Spring 2018; 45(2):23-24. Available from: Business Source Complete, Ipswich, MA. Accessed June 26, (2018).
- Budding T, Grossi G., Public sector accounting. Taylor and Francis. New York and London, (2014).
- Darono, A., & Ardianto, D., The use of CAATTs in tax audits-lessons from some international practices. *EJournal of Tax Research*, 14(2), 506-526, Retrieved from <http://0-research.proquest.com.www.elgar.govt.nz/docview/1858088910?accountid=40858>, (2016).
- Davidson, J. S., The demise of Indonesia's upstream oil and gas regulatory agency: An alternative perspective. *Contemporary Southeast Asia*, 37(1), 109-133.doi:<http://dx.doi.org.aucklandlibraries.idm.oclc.org/10.1355/cs37-1e>, (2015).
- Farr L. Future of the audit. *Journal of Accountancy* [serial online].August 2017; 224(2):2-3. Available from: Business Source Complete, Ipswich, MA. Accessed June 26, 2018.
- Fleener, William C., Implication on Computers in Financial Statement Audits. *Journal of Accountancy*. New York, 179(4), 91-93, (1995).
- GAO-06-729G, Public Sector auditing standards. United States general accounting office by the comptroller general of the United States, (2006).
- GAO/OP-4.1.2, United States general accounting office. Office of policy, (1989).
- Gauthier S.J., Better understanding the financial statement audit. *Govt Fin Rev* 25(3):44–48, (2009).
- Public Sector finance statistics manual, International Monetary Fund, Washington, DC, (2014).
- Lewis A.C., Neiberline C., Steinhoff J.C. Digital Auditing: Modernizing the Public Sector Financial Statement Audit Approach. *Journal of Public Sector Financial Management*, Spring 2014, 63, 1, pp 32-37, (2014).
- McCollum T.,Audit in an age of intelligent machines. (cover story). *Internal Auditor* [serial online]. December 2017; 74(6):24-29. Available from: Business Source Complete, Ipswich, MA. Accessed June 26, 2018.

## Is outsourcing the best solution in increasing organisational performance?

Olga Bucovetchi<sup>a\*</sup>, Radu D. Stanciu<sup>a</sup>, Dorel Badea<sup>b</sup>

<sup>a</sup>University “Politehnica” of Bucharest, 313, Spl. Independentei, Bucharest, Romania

<sup>b</sup>“Nicolae Bălcescu” Land Forces Academy Sibiu, 3-5, Revoluției St, Sibiu, Romania

---

### Abstract

In the last decades, a broad range of activities has been grouped under the logistics term. For a long time, it has only been limited to external flows, i.e. transport and distribution. Nowadays, the high complexity of the logistics function leads to a situation where industrial and trade enterprises outsource more and more their logistics activities. As a consequence of the outsourcing phenomena, the logistics sector has grown, becoming a sector of self-employment. It became a new economic area, which besides transportation includes storage, handling, IT, consultancy services, etc. Logistics activity has met important developments that have made it develop from the support function within the enterprise to a cross-business function between businesses. The purpose of the present research is to analyze which of the two options - internal logistics department or outsourcing of logistics services - is the best when managers aim business performance. There were defined several KPIs (key performance indicators) that were assessed as the authors addressed to performance management as a multi-criteria decision analysis.

*Keywords:* business; logistics; outsourcing; performance

---

### 1. Introduction

Logistics has evolved over the last few years in an accelerated way by transforming it from an internal support activity into a new link between companies. The logistics function has increased in complexity, therefore both industrial and commercial organizations have had to reshape to the outsourcing of their logistics sectors, thus allowing for the emergence of a logistics market. The logistics market is evolving constantly and rapidly, being marked by many large and structural directions

Logistics activity is traditionally divided into two essential forms. (Cohen, L. and Young, A., 2006). One improves the continuous flow of raw materials, products and materials through a transport network and storage centers, making so-called global logistics. The second part directs a part of the enterprise's resources to carry out a specific activity: the logistics of certain activities in the enterprise (transport logistics, storage logistics, and logistics of supply).

In 2004, Corbett defines outsourcing as a management tool to drive an enterprise from its traditional, vertically integrated structure, an organizational structure that no longer meets the demands of an increasingly competitive economic environment, increasingly oriented towards performance.

Outsourcing helps the enterprise to change its business structure into a structure capable of making specific investments in areas closer to the unique advantage it has. In logistics, outsourcing is a phenomenon that is experiencing massive growth. Companies that are active in this area have grown more and more and competition has become more and more fierce.

Given these, the purpose of the present research is to analyze which of the two options - internal logistics department or outsourcing of logistics services - is the best when managers aim business performance.

---

\* Olga Bucovetchi. Tel.: +40-21-402-9106.  
E-mail address: olga.bucovetchi@upb.ro.

## 2. Methodology

The method used during the primary research is the survey and the tool – questionnaire. Furthermore, after a significant literature review, there were defined several key performance indicators (KPIs) that were assess in order to see the impact of each KPI in choose in favor or not to outsourcing. (Jennings, D., 1997, Dolgui, A and Proth, JM, 2010, Lin, N. et al, 2016)

The questionnaire was applied to 30 small and large companies, both local and multinational, with Romanian and foreign capital. The 9 questions in the questionnaire wanted to encapsulate the most important information about the chosen topic, focusing on the key performance indicators that influence the decision in choosing or not outsourcing.

In the case of this research, the purpose is to clarify which of the two options is best suited for the companies for which this department is needed - own logistics or outsourcing of logistics services. Confirmation or invalidation of the hypotheses of this research was achieved by analyzing the answers obtained within the questionnaire. There were made the following assumptions:

- Most customers are more than 500 kilometers away from picking points.
- Most of the goods transported are light and compact, which makes logistics processes more efficient.
- The main trend among large companies is to outsource logistics services to third parties.
- Most companies see logistics as a department of tactical importance.
- Most companies outsourcing logistics activities are satisfied with the services they receive.

## 3. Research results

The first question of the questionnaire concerned the size of the company. When analyzing the responses, one can see that the majority of respondents, namely 40%, indicate medium enterprises with staff members between 50 and 249 employees in Romania; second place is occupied by large enterprises (more than 250 employees) in proportion 27% (see fig. 1).

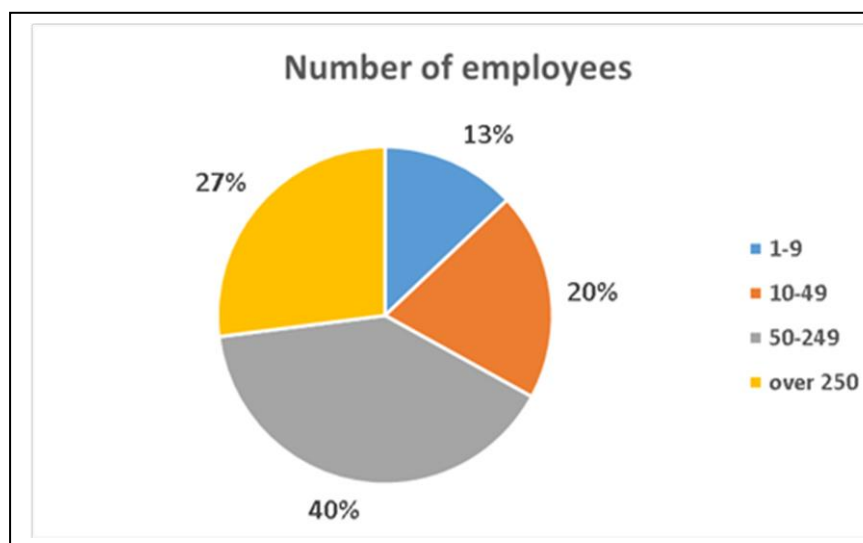


Fig.1 Categories of organizations

As far as "the distance to which most of the customers are," is concerned, the answers are as follows: 30 percent of the respondents said that most of their clients are at distances between 150 and 499 km, respondents whose customers are between 75 and 149 km are the second place with 27%. The customers with distance over 500 km away from picking point are, in the proportion of 13%. Thus, the "Most customers are over 500 km away" hypothesis is not confirmed.

Furthermore, the respondents were asked to join the four freight types with their frequency to verify the hypothesis that most of the goods produced and / or marketed are light and compact and thus all logistics processes are more efficiently achieved. The result are emphasized in fig. 2; one may easily conclude that the second hypothesis was confirmed.

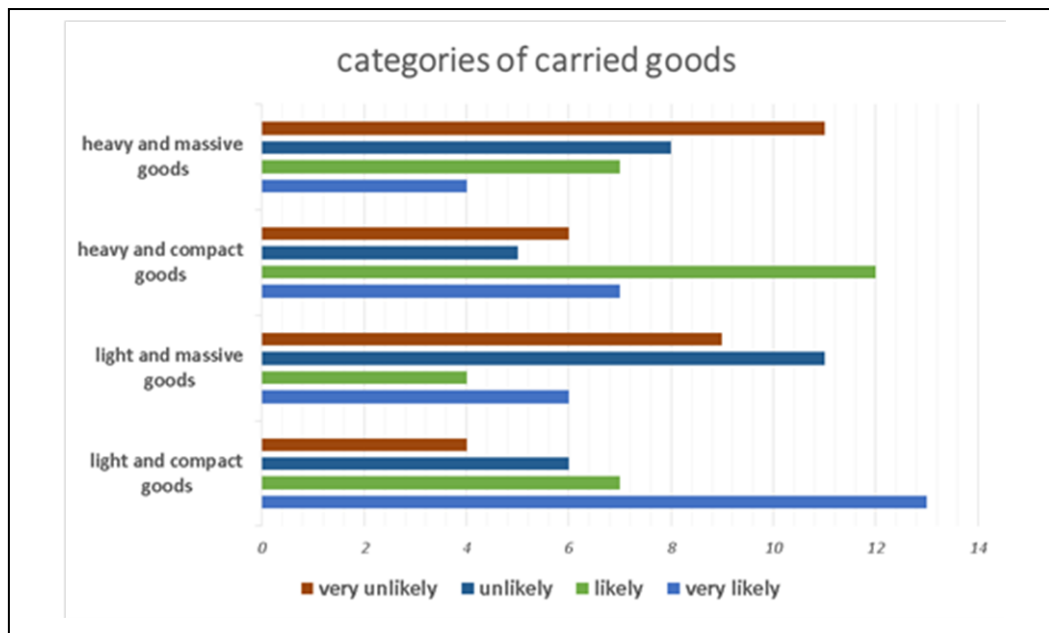


Fig. 2. Categories of carried goods

Being asked "In what type of warehouses do you keep the goods?" most respondents chose "rented warehouses" - 43%. On the second place are the companies that use both leased warehouses and their own warehouses, namely 37%. 13% are those companies that use exclusively their own deposits. Only 6 percent of respondents said that deposits are unnecessary, with a perfect balance between the goods produced or purchased and the merchandise sold. Analyzing the results of the research, one can confirm the hypothesis that "the main trend among big companies is to outsource logistic services to third parties", at least as regards the storage of products. (see Fig. 3).

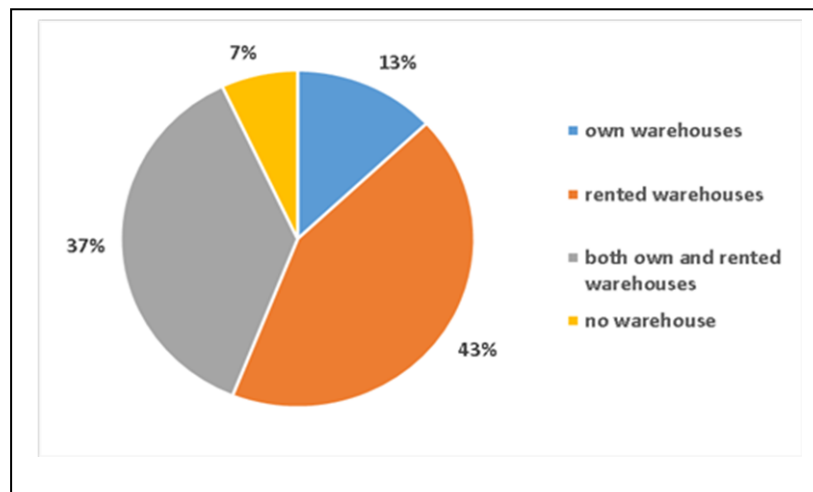


Fig. 3. Types of warehouses to keep goods

Question 6, "Does your organization have a logistics department," was designed to make the research as relevant as possible; companies that do not need dedicated logistics staff were not part of the target group of this research. Only two of the interviewed companies said they did not need dedicated staff and did not respond to the rest of the questionnaire questions, with the remaining 93% of respondents. Most of the logistics departments of the respondents have more than 10 employees (48%), 41% have between 5 and 9 employees and 15% no more than 4 employees.

There were defined six elements that weight in decision making process of outsourcing or not the transport of products. Those elements were evaluated in terms of satisfaction or dissatisfaction. Once an organization is satisfied with the results of externalizing an activity (they give 5 points for that indicator) it's more likely to continue to decide to make outsourcing permanent.

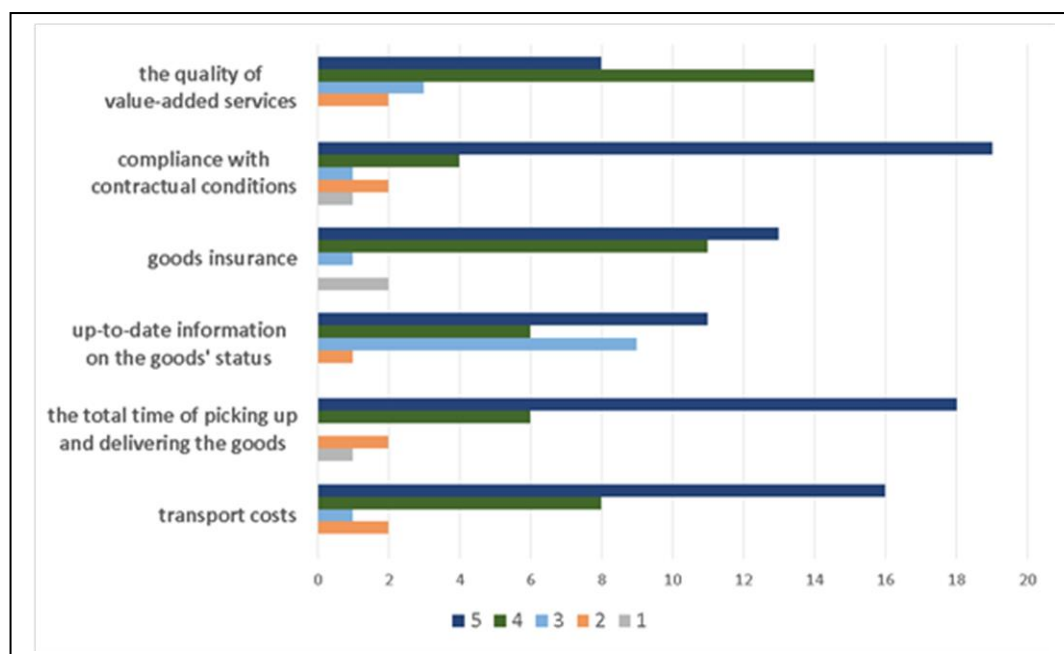


Fig. 4. Key elements in decision making process

The most important thing a company's logistics manager can do is to evaluate both the company's activity (internal logistics) and the offers found on the market (the companies offering the services that want to be outsourced) according to the same key performance indicators.

These indicators must be objective and significant to organizational. Moreover, the above-mentioned analysis needs to be restored whenever one or more factors of the company's external or internal environment change. Also, the market trends are particularly important for an enterprise that wants to compete

#### 4. Conclusions

“One of the various conditions of successful business is to be able, in the long term, to focus the effort and the resources on the core company activities” (Milecova, M. et al, 2010). Organizations often benefit from focusing on basic operations and outsourcing outreach activities to specialists. These peripheral activities could be anything from cleaning and catering to accounting, legal services and information processing. Logistics is a very popular feature for outsourcing, with specialist service providers taking over part or all of the materials for movement and storage. This use of 3rd party logistics (3PL) has the usual benefits of low fixed costs, service experts, economies of scale, flexible capacity, lower risk exposure, increased geographic coverage and guaranteed service levels.

Sometimes managing multiple 3PL contracts becomes so complicated that another company is used to manage it - creating the fourth logistics part (4PL).

#### References

- Cohen, L., Young. A., *Moving Beyond Outsourcing to Achieve Growth and Agility*. Harvard Business School Press, (2006)
- Corbett, M.F. *The Outsourcing Revolution: Why It Makes Sense and How to Do It Right*, Ed. Berkshire Kaplan, (2004)
- Dolgui, A., Proth, J.M., *Supply Chain Engineering: Useful Methods and Techniques*, Springer, DOI: 10.1007/978-1-84996-017-5 (2010)
- Jennings, D., Strategic guidelines for outsourcing decisions, *Strategic Change*, Vol. 6, pp. 85-96, (1997)
- Lin, N, Devinney, TM and Holcomb, TR., Examining Managerial Preferences and Choice: The Role of Value Creation and Value Appropriation Drivers in Strategic Outsourcing: *Long Range Planning*, Vol 49, No. 6, pp. 706-722, (2016)
- Milecova, M., Grznar, M., Szabo, L., Outsourcing: Decision making in the case of outsourcing the company activity and the management of outsourcing project, *Agricultural Economics-Zemедельска Економика*, Vol. 56, Iss. 8, pp. 387-396, (2010)



## Trade Marketing – An Innovative Concept in Logistic Cooperation between Manufacturers and Traders

Oana Dobre-Baron<sup>a\*</sup>, Alina Nițescu<sup>a</sup>

<sup>a</sup>University of Petroșani, Str. Universității nr. 20, 332006, Petroșani, Romania

---

### Abstract

Interdependence between producers and traders has not always been a collaborative relationship, but rather a conflicting one in which both parties pursue their own interests. The expansion of mass production, the emergence of large commercial areas and the globalization process have led to a reconsideration of the role of traders in their relations with producers, becoming strategic partners and at the same time a target of manufacturers marketing policies. Thus, three innovative concepts emerge and develop over the years: Trade Marketing, Category Management and Efficient Consumer Response. One of the longest-living and most successful American companies, Procter & Gamble, is the one that has innovated the concept of Trade Marketing as a convergence between the marketing of the trading company and the marketing of the manufacturer. This paper aims to analyze this concept and emphasize the role that P & G has had in reconsidering the position of the manufacturer in the logistic cooperation between him and the trader.

*Keywords:* trade marketing; supply chain partnership; logistic cooperation; manufacturer; retailer; consumer; customer

---

### 1. Trade Marketing – general considerations

During the 1990s, the dynamic in relations between manufactures and distributors changed. The concept of Trade Marketing had appeared as an attempt of a form of partnership between manufactures and distributors, which has put a significant mark on relations between commerce and industry. Trade Marketing marks the moment in which, for the producer, no longer does the final consumer represent the only source of creating the fiscal and profit values, but also the distributor, which surpasses the passive role it has fulfilled up to that point, becoming a principal facilitator in the success of sales. (Vasiliu et al., 2010)

#### 1.1. The evolution of relations between manufactures and traders

Commerce is an activity sector engaged in continuous evolution, being influenced by a variety of factors, among which the following should be mentioned: production, consumption, transport conditions, technology, facilitating services (banking sector, logistical services, marketing firms which conduct a variety of studies, consulting societies etc.).

Production has influenced the evolution of commerce through the increasingly abundant and diversified offer, which translates into the expansion of markets and the necessity of exposing a growing number of products.

Consumption has evolved under the action of certain demographic (size and evolution of the population. average lifespan, household size etc.), economic (buying power, income size etc.) and sociological (through the vehiculation of topics related to environmental and health concerns, for physical aspect, for safety etc.) factors.

Transport has benefited over time from the appearance and spreading of long-distance means of travel (aerial, railway and naval), which brings together places of production and of consumption. Furthermore, over the last few decades, the car has represented a factor which has encouraged population migration towards the periphery of urban

---

\* Oana Dobre-Baron. Tel.: +400722553771;  
E-mail address: oanabaron2014@gmail.com.

areas, determining the emergence of commerce situated on the edge of major urban agglomerations, which has led to changes in consumption habits and lifestyles.

Technological progress manifests itself in the domain of commerce through the use of software development, of the scanner and of the means of telecommunication. They have led to changes in managerial practices, modes of managing products and stocks, relations between business partners, to the appearance of new apps in various connected fields – logistics, marketing, training and recruitment of personnel etc.

Facilitating services are in full evolution as well. The nature of relations between commerce and financial institutions, in general and banks in particular – sales in installments, cashing using credit cards, diverse credits etc. is changing. Transport and logistics companies are closely following the evolution of commerce, being closely tied to it. Marketing and consulting firms, too, are developing instruments applicable to commerce and proposing solutions adapted for this sector.

As a result of the action of these factors, commerce is becoming a sector which a large capacity of innovation regarding utilized concepts, ways of commercial management, offers directed towards clients, selling techniques, types of enterprises etc.

In this context, relations between producers and traders can be better understood, their evolution over the past few decades being able to be structured in four stages, as follows (Vasiliu et al., 2010):

- The first stage, begins in the 1950s, years marked by powerful economic growth and the beginning of mass production. During this time, there appeared the first superstores. Distribution in this period of time still remains only lightly concentrated, manufactures wielding the largest negotiating power, resulted from the larger force and, as such, are the ones which impose conditions in the largest capacity. Marketing specific to this period is oriented towards a production optic. Producers are preoccupied with placing products on market segments utilizing mass marketing. Distributors are regarded as passive entities, fulfilling the middle role of circulating products from the producers to the consumers. What follows is a period of progressive rebalancing in the relations between producers and distributors in which the latter privileges the strategies of small prices. Producers adopt a marketing in which the main focus becomes selling.
- The second stage begins with the 1970s financial crisis, when economic growth slows and the negotiating power of large trading enterprises becomes stronger due to the increased power of distribution firms. During this period a boom in large selling surfaces occurred, as well as the tendency of focusing of important firms. As such, buying conditions change, the role of purchasing centres strongly rising in importance. Consumption-centred marketing begins to be accompanied by trader-centered marketing. Department management and management of selling space are expanded, words like merchandising, key accounts, assortment management etc. becoming popular.
- The third stage begins in the 1990s when the concept of trade marketing appeared, as the common will of producers and distributors of transitioning from previous conflicting relationships to those of cooperation. The interdependence between the two forces them to realize that both of them require the other part as well, being unable to ignore the existence and interests of the other component. Manufactures become conscious of the role of traders and, as such, the latter become a target of the marketing policies of the former. Manufactures begin to consider the retailers as strategic partners with which relationships much be tightened and maintained. Producers extend individual promotion campaigns, realize plans for clients, attempting the development of an intense cooperation with distributors. The end results of this phase are not spectacular because producers often only refer to reductions for pushing their products on the retailers' shelves. Cooperation between the two partners effectively manifests only in the domain of promotion campaigns.
- The fourth stage is known as "partnership". Partnership is an umbrella concept which includes the circulation of information and integral management of the logistics chain, paving the way for a vast domain of cooperation. Partnership is no longer a unilateral option, as it is initiated jointly by producers and distributors. It is the moment when two other concepts also appear, namely Category Management and Efficient Consumer Response (ECR).

### *1.2. Trade Marketing – conceptual boundaries*

Despite being a new concept which has appeared only recently, Trade Marketing has enjoyed, in its defining, different approaches. Today, authors of prestige as well as those interested and involved in the field have given the same content of the definition's concept.

As such, Philip Kotler and his collaborators have emphasized: "Trade marketing represents the business to business concept of marketing, which treats the distributor as a client. Its objective consists of identifying the individual expectations of every distributor in order to develop long-term personalized relationships. Trade marketing is involved in assortments, product policies, merchandising, logistics and promotion."

Regardless of whether they are more succinct or whether they detail the essence of the concept, other definitions relay the same definition as well: "Trade marketing, to put it simply, is a B2B marketing strategy aimed at getting a product onto store shelves. This is done by making other businesses recognize the value of your product, and convincing them that helping you sell your product will ultimately help them make money too. The purpose of trade marketing differs from that of traditional marketing, as it is not focused on the final sale. Instead, trade marketing focuses on the means by which that final sale is made. You need to get your products in front of consumers before they

can make the decision to purchase them.” (Sonntag, 2017); “Trade marketing is a form of B2B marketing. It’s the art of marketing products specifically to businesses... Normally, the objective of a trade marketing campaign is to sell products to companies who can then go on to sell those items to their customers.” (Press, 2018).

We have previously established that today, between producers and traders there exist relations of partnership. The number and type of partners differ on a case by case basis, depending on the distribution channels used by the producers. They are actually those which utilize trade marketing.

The aim of trade marketing for a manufacturer is to increase demand for their product with supply chain partners. A sales chain partner is a person or business that’s involved in the movement of products in commerce (and, as such, is the collective term for distributors, wholesalers and retailers). The process is simple: For a product to be sold in a shop, the retailer first needs to purchase the item from somewhere. Retailers will buy products either directly from a manufacturer, or via a wholesaler or distributor. The retailer will then sell those products to the public.

Manufacturers need trade marketing methods to try and create demand for a product with retailers, wholesalers and distributors and the aim is always the same: to sell a product that can then be resold. In another train of thoughts, manufacturers must market a product before it reaches the consumer because regardless of whether a retailer is buying a product from a wholesaler, a distributor or directly from a manufacturer, the retailer obviously still gets to choose which items they want to sell. The retailer is in the position of power. As such, there’s an ongoing battle to get products in front of retailers and into their stores so that it can be sold. Trade marketing is the difference between a retailer choosing one product to sell over another. And whether a product gets pushed or not affects everyone in the supply chain (but mostly the manufacturer of the product). (Press, 2018).

Today there are lots of different trade marketing methods that a manufacturer can use. The most widely used strategies are: trade shows; trade promotions; trade magazines and websites; branding; relationships; ongoing market research; digital marketing.

For these strategies, producers need adequate tools. These are differentiated as such:

As far as digital trade marketing is concerned, they are: an efficient website; various social media platforms; email marketing software; landing pages for lead generation; branded content.

For physical trade marketing the tools are: posters, display boards, kiosks, banners, stalls, brochures, flyers and business cards.

## **2. The Procter & Gamble Company – general overview**

Procter & Gamble (P & G) is one of the largest producers of non-alimentary consumer goods worldwide with annual sales of over \$65 billion and total assets of over \$130 billion.

Founded in 1837 by William Procter and James Gamble, the Procter & Gamble Company started as a small family business which produced candles and later soap, in Cincinnati, Ohio state, USA. The company triggered its first “revolution” in industry in the 1940s with the launch of detergent brand Tide. Beginning with the 1970s, the company has known a significant development through the launch of several new products, including: dish soap (1972), the first Duracell battery (1974), Always absorbents (1983), Head & Shoulders shampoo (1986). One of the most important events in the company’s life happened in 2005 when Procter & Gamble bought the rival company Gillette for the sum of \$57 billion.

Presently, Procter & Gamble is a multinational company operating in 70 different countries which has over 95.000 employees. P & G products are commercialized in over 180 countries all around the world and are consumed by over 5 million people globally.

Procter & Gamble has in its portfolio 23 product brands which generate annual sales between \$1 and \$10 billion, and 14 brands generate sales between \$0.5 and \$1 billion, continuing to have a huge potential for growth. Procter & Gamble contains in its portfolio two out of the first 100 most valuable brands globally, as shown by the ranking done by Forbes Magazine for the year 2016. This way, the Gillette brand occupies the 26th place, being evaluated at \$20.4 billion while the Pampers brand occupies the 49th place, being evaluated at \$11.1 billion. ([https://www.brkfinancialgroup.ro/fileadmin/user\\_upload/Brosuri/Analiza\\_prezentare\\_P\\_G.pdf](https://www.brkfinancialgroup.ro/fileadmin/user_upload/Brosuri/Analiza_prezentare_P_G.pdf))

The operational results of Procter & Gamble are presented on 5 business segments: Beauty (18% of sales made in 2017, 19% of profit achieved in 2017); Grooming (10%, respectively 16%); Health Care (12%, respectively 13%); Fabric and Home Care (32%, respectively 27%) and Baby, Feminine and Family Care (28%, respectively 25%). (<http://www.pginvestor.com/PG-at-a-Glance/Index?KeyGenPage=1073748355>)

The business segment with the largest share, 32% from all net sales is represented by „Fabric and Home Care”. On the opposite side of the spectrum, with a percentage of only 10%, there is the „Grooming” segment. In the case of the net profit generated by each business segment, „Fabric and Home Care” is still at the top, with 27%, closely followed by baby, feminine and family care products, on last place being, with 13% from the total, health care products.

Over the course of the year 2017, the company has finished its previously announced plan of making the product portfolio significantly more efficient through yielding, giving up or consolidating approximately 100 non-strategic brands. The resulting portfolio, of approximately 65 key brands, is contained in 10 product categories, those being business segments where P & G has the position of market leader, strong brands and production technologies relevant to consumers. (P & G, *Annual Report*, 2017)

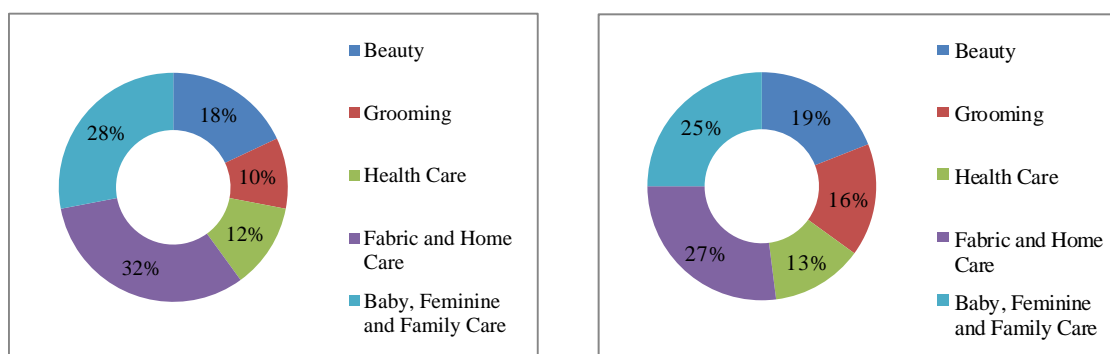


Fig. 1. (a) Net sales by business segment (2017); (b) Net profit by business segment (2017)

At a global level, the main competitors of Procter & Gamble are: Unilever NV, L'Oreal SA, Colgate Palmolive Co and Kimberly-Clark Corp. It can be observed from the data contained in Table 1 the fact that in matters regarding sales, as well as net profit obtained in 2015, P & G is in first place. ([https://www.brkfinancialgroup.ro/fileadmin/user\\_upload/Brosuri/Analiza\\_prezentare\\_P\\_G.pdf](https://www.brkfinancialgroup.ro/fileadmin/user_upload/Brosuri/Analiza_prezentare_P_G.pdf)) The main competitor of the company is Unilever NV which, despite being in second place, has had less sales than P & G by \$24.4 billion. With regard to net profit, it has nearly been twice as small.

Table 1. Main competitors on the consumer goods market

Company	Net sales (\$ bill)	Net profit (\$ bill)
Procter & Gamble	83	11,5
Unilever NV	58,6	6,3
L'Oreal SA	27,3	5,9
Colgate Palmolive Co	17,3	2,3
Kimberly-Clark Corp	19,7	1,4

The company's business model is based on continual economic growth and on the success of brands and existing products, as well as creating new products. The markets and industry segments in which these products are offered are extremely competitive. P & G products are sold in more than 180 countries and territories primarily through mass merchandisers, e-commerce, grocery stores, membership club stores, drug stores, department stores, distributors, wholesalers, baby stores, specialty beauty stores, high-frequency stores and pharmacies.

Net sales registered in the USA arrive at 42% of total net sales. No other individual country surpasses 10% of total net sales. Operations outside the USA are generally characterized by the same conditions outlined in the description of the business at a global level above and can be affected by additional factors, such as changes in exchange rates, different rates of inflation, economic growth, but also doubts and political and economic turmoil. Company sales on geographical regions are presented in Table 2. (P & G, *10-K Report*, 2017)

Of course, the largest percentage of total sales is of North American sales, registering a 3% increase in 2017 from 2015. The largest and most important client of P & G is the American company Wal-Mart, which is currently the largest retailer in the world.

Sales towards Wal-Mart Stores, Inc. and its affiliates represent approximately 16% of total company sales in 2017 and 15% in 2016 and 2015. No other client represents more than 10% of total sales. The first ten clients have represented approximately 35% of total sales in 2017, 2016 and 2015.

Table 2. Structure of P & G' sales per geographical regions

Region	2015	2016	2017
North America (USA., Canada and Puerto Rico)	41 %	44 %	45 %
Europe	24 %	23 %	23 %
Asia and the Pacific	8 %	9 %	9 %
China	9 %	8 %	8 %
Latin America	10 %	8 %	8 %
IMEA (India, Middle East and Africa)	8 %	8 %	7 %

The company's management considers that it should continue offering new, innovative brand name products to consumers in order to develop its business. Consequently, its marketing and research activities – development of products, conceived to allow permanent, sustained, organic growth, have continued and will continue to have a high priority every year. (P & G, 10-K Report, 2017)

### 3. The Procter & Gamble Company – an innovator in Trade Marketing

Markets in which P & G products are sold are extremely competitive. Its products compete with similar products of many big and small companies, among which there are known global competitors. The company's products are supported by publicity, promotions and other marketing channels with the aim of informing the consumer about its existence and the necessity to buy them, together with an extensive selling force. Company management considers that this combination offers the most efficient marketing method for these types of products. Product quality, performance, value and packaging are also important differentiating factors. (P & G, Annual Report, 2017)

But things haven't always been like this. Under the old management system P&G had 12 national sales forces, each hawking a product line such as detergents or foods. Retailers were faced with numerous P&G salesmen pushing 12 different product lines with all sorts of different promotions. At that moment producers dominated the market and imposed their products. Then the balance of power shifted from big manufacturers like P&G to the retailers. What tipped the scales was consolidation among supermarket and drugstore chains and the widespread use of scanners at the checkout counter. Electronic bar coding helped retailers gather their own sales data. Analysts have considered that from that moment P&G could no longer bully its way into the stores, waving figures a retailer couldn't dispute. Slowly P&G realized that it would have to start fussing over these power-punching retailers and switch from a product to a customer approach. This way in the summer of 1987, the company began organizing its 4,000-strong sales force to do something pretty obvious: focus more on the customer, in this case, supermarkets and department stores. (Dumaine, Kuhn, 1989) One of the most important clients of P & G was Wal-Mart. At that time, the relationship between P & G and Wal-Mart was characterized as anything but collaborative. As a matter of fact, their relationship was adversarial, obsessed by day-to-day transactions. Wal-Mart did not like doing business with P & G because P & G organizations were too complicated and inflexible. P & G were obsessed by day by day selling. Efforts were made to push for sales irrespective of what the customer needed, or was rewarded for. There were no testing or long term planning. Relationship and activities were managed by the buying and selling function only. The selling function within P & G was responsible for all customer activity. They were responsible for selling at the customer. The role that information systems played in the relationship was non-existent. (Grean, Shaw) It was obvious that things would not continue in this manner for long.

In 1988, after a discussion between the top managers of the two companies, both unhappy with the way its business partner was only acting in self-interest, but especially the lack of information from both ways, P & G formed a team of analysts which, in the course of a few months, would work at the headquarters of Wal-Mart. They understood, with astonishment, that the fragmented system of division based selling of company products heavily encumbered the work of the trader, meaning lost time and money. Furthermore, the information which the manufacturer had regarding sold products did not coincide with those of the trader. Walmart had loads of data that came from scanners in all of their stores. P & G had data that it used to develop products. By putting the information together they could answer questions like "what products do customers buy and why?". By analyzing Walmart's in-store data, the companies, working together, were able to eliminate losing products from store shelves and replace them with winners, thus increasing sales. (Gray, Vander Wal, 2014)

Thus it isn't surprising that the two companies have decided to take their collaboration to the next level and to create values for both through the channel partnership. To emphasize the strong commitment to develop this mutually beneficial partnership, the P & G and Wal-Mart team developed a mission statement, which reads: *"The mission of the Wal-Mart/P & G business team is to achieve the long-term business objectives of both companies by building a total system partnership that leads our respective companies and industries to better serve our mutual customer - the consumer."* (Grean, Shaw)

The partnership started with the simple desire to improve business relationships, and was gradually enhanced by sharing information and knowledge about their respective markets. The process has been possible because of technology, which has played a key role in logistical cooperation between the two companies and has relied on using the following instruments: joint scorecards and measurements; driving out costs through automation; sharing data to better understand the consumer and drive sales. This sharing in turn enabled more effective execution of such concepts as category management, continuous replenishment, and process coordination, which collectively helped make the supply chain more efficient.

We know today that an important strategy for managing integrated supply chains is to share information among supply-chain partners. One of the main benefits of sharing information is the reduced need for inventory. As a result, the supply chain achieves better performance in terms of financial returns, service level, and turn-around times. P & G and Wal-Mart have been the first to understand the importance of collaborating in the supply chain. With information shared among the manufacturer and the retailer, the manufacturer can use the information about the inventory level of the retailer to manage the frequency, quantity, and timing of the shipments-- instead of waiting for the retailer to place

orders. This practice, referred to as continuous replenishment process (CRP), enables the manufacturer to reduce the inventory necessary and to plan the shipments more efficiently, as has been implemented by P & G and Wal-Mart.

Moreover, P & G and Wal-Mart have improved the profitability of both companies by using multifunctional resources to drive out costs and improve sales. The two organizations use joint scorecards to review the joint business and make annual plans to drive category growth for both companies. Together they use technology as a method to drive out costs, and openly share data to better understand their joint customer - the consumers. (Grean, Shaw)

#### 4. Conclusions

The P & G Company, as a producer, has been the first to understand that, despite its products being marketed towards final consumers, its client is the trader, which has the same point of interest. With the aid of one of its most important clients, retail company Wal-Mart, P & G has become aware of the strategic benefit of partnership based on innovation inside the supply chain. This has led to the adoption of business to business, which, in essence, relies on the fact that the producer must help the trader which, further on, will sell its products towards the final consumer. And this is, in fact, the essence of Trade Marketing.

#### References

- Balaure, V. (coord.), *Marketing*, 2nd Edition revised and added, Uranus Publishing house, București, (2003).
- Bălan, C., *Logistica*, 3rd Edition revised and added, Uranus Publishing house, București, (2006).
- Dumaine, B., Kuhn, S., *P&G rewrites the marketing rules*, Fortune Magazine, November 6, 1989, Available online at: [https://money.cnn.com/magazines/fortune/fortune\\_archive/1989/11/06/72715/index.htm](https://money.cnn.com/magazines/fortune/fortune_archive/1989/11/06/72715/index.htm), accessed on 25<sup>th</sup> of August 2018.
- Gray, D., Vander Wal, T., *The connected company*, O'Reilly Media, Inc., Available online at: <https://books.google.ro/books?id=hVn9UkWqHIIC&pg=PA262&lpg=PA262&dq>, accessed on 25<sup>th</sup> of August 2018 (2014).
- Grean, M., Shaw, M.J., *Supply-Chain Integration through Information Sharing: Channel Partnership between Wal-Mart and Procter & Gamble*, Available online at: <https://pdfs.semanticscholar.org/1a84/541d164cfdec6ed4d16a82548839d7026630.pdf>, accessed on 25<sup>th</sup> of August 2018.
- Kotler, P., Dubois, B., Manceau, D., *Marketing management*, 11<sup>e</sup> edition, Pearson Education, Paris, (2004).
- P & G, *Annual Report, 2017*, Available online at: <http://www.pginvestor.com/Cache/1001226614.PDF?O=PDF&T=&Y=&D=&FID=1001226614&iid=4004124>, accessed on 23<sup>th</sup> of August 2018.
- P & G, *10-K Report, 2017*, Available online at: <http://www.pginvestor.com/Cache/1001242065.PDF?O=PDF&T=&Y=&D=&FID=1001242065&iid=4004124>, accessed on 23<sup>th</sup> of August 2018.
- Press, M., *A guide to trade marketing and the best strategies and techniques*, Available online at: <https://www.splashcopywriters.com/blog/trade-marketing>, accessed on 15<sup>th</sup> of August 2018, (2018).
- Sonntag, M., *Trade marketing: Everything You Need to Know (And Nothing You Don't)*, Available online at: <https://www.repsly.com/blog/field-team-management/trade-marketing-everything-you-need-to-know>, accessed on 15<sup>th</sup> of August 2018, (2017).
- Vasilu, C., Felea, M., Mărunțelu, I., Caraiani G., *Logistica și distribuția mărfurilor – note de curs*, Available online at: <https://adrianabuzdugan.files.wordpress.com/2010/09/carte-logistica.pdf>, accessed on 20<sup>th</sup> of August 2018.
- Waller, M., *How sharing data drives supply chain innovation*, Available online at: <https://www.industryweek.com/supplier-relationships/how-sharing-data-drives-supply-chain-innovation>, accessed on 25<sup>th</sup> of August 2018 (2013).
- \*\*\* [https://www.brkfinancialgroup.ro/fileadmin/user\\_upload/Brosuri/Analiza\\_prezentare\\_P\\_G.pdf](https://www.brkfinancialgroup.ro/fileadmin/user_upload/Brosuri/Analiza_prezentare_P_G.pdf)
- \*\*\* <http://www.pginvestor.com/PG-at-a-Glance/Index?KeyGenPage=1073748355>

# Analysis of the Romanian Agricultural Sector in European Context

Alina Nițescu <sup>a\*</sup>, Oana Dobre-Baron<sup>a</sup>

<sup>a</sup> University of Petrosani, University Street, N<sup>o</sup>. 20, Petrosani, 332006, Hunedoara County, Romania

---

## Abstract

In recent years, the Romanian economy is part of the economies in Europe with notable economic growth. It is the economy where the industry plays a major role but also has great potential in the agricultural sector due to favorable natural conditions. Agriculture plays an important role in Romania, relative to the size of the rural population and to the primary natural resources they own. However, there are major differences between rural and urban areas, the former being marked by a significantly higher level of poverty and a correspondingly lower living standard. The development of agriculture and the provision of public goods in rural areas is therefore essential for Romania's economy and for achieving the objectives of social cohesion. Compared to other EU countries, the Romanian agricultural sector has a relatively high share in gross added value but has lagged behind in terms of labor productivity.

*Keywords: primary sector, agriculture, agricultural policy*

---

## 1. Introduction

The role of the primary and general sector and of agriculture in particular is an indisputable one. The agricultural sector is in close connection with other sectors of the economy, especially with the industrial sector and contributes to economic development.

Over time, the agricultural sector has evolved and can be characterized by three stages: the first stage addresses the preconditions for agricultural development - which relate to the improvement of the land structure, access to the consumer goods market, information on available techniques; the second step is to increase the efficiency of agricultural production processes by spreading innovation "labor intensive" and "saving capital"; the third and final phase of the evolution of agriculture is characterized by "intensive capital" and "labor saving" technology. This phase is that of the industrialization of agriculture.

A process of structural transformation is taking place globally as a result of the emergence of new global challenges with a long-term effect, which require a strategic vision in the field and concrete actions by the competent authorities. The growing global population, increased pressure on natural resources and global warming are creating a new framework at national and international level. In Europe, the aging process is also an additional challenge. All these aspects will have profound implications for agriculture and rural areas.

World food demand is on the rise, increased urbanization, rising input prices, pressure on water resources and growing crop and animal vulnerability to climate change will limit food production.

It is forecast that global demand for food will increase by 70% by 2050 as a result of the growing population and increased revenue. Developing countries will contribute most to this trend, with their demand for food to double in the coming years.

For the agri-food sector, these issues are both an opportunity and a challenge. Growth prospects for the agri-food market constitute a significant advantage for farmers around the world. However, imperfect market infrastructures and socio-economic vulnerabilities in the most densely populated areas of the world are expected to increase food insecurity. In addition, world agricultural systems will increasingly face the negative effects of climate change (changing rainfall

---

\* Corresponding author. Tel.: +40722503696.  
E-mail address: al.nitescu@gmail.com.



patterns, extreme weather phenomena, water shortages) as well as price volatility. On the other hand, increasing agricultural productivity can be achieved through investment, research and innovation, good agricultural practices and adequate public policies.

Although agriculture has always focused on food security and has been a positive engine for economic growth, the growing concern of the environmental society in recent decades has affected global agricultural policies. Consumers have become more and more concerned with the environmental sustainability of agriculture. The desire to know where the food comes from, how it was produced, and whether farming practices respect the environment are just some of the demands of today's consumers.

## 2. Characteristics of the Romanian agricultural sector in the European context

Agriculture was the main component of the primary sector in all Member States. According to the national accounts around 10 million people worked in agriculture in the EU-28 in 2015 and accounted for 4.4 % of total employment. Almost three quarters (72.8 %) of the agricultural workforce in the EU-28 was concentrated in seven countries: Romania, Poland, Italy, France, Spain, Bulgaria and Germany. ([https://ec.europa.eu/eurostat/statistics-explained/index.php/Farmers\\_in\\_the\\_EU\\_-\\_statistics](https://ec.europa.eu/eurostat/statistics-explained/index.php/Farmers_in_the_EU_-_statistics))

Agriculture plays an important role in Romania, relative to the size of the rural population and to the level of employment. About 45.7% of the Romanian population lives in rural areas, compared to about 23.6% in the EU member states. About 30% of the population is engaged in agriculture, compared to about 2% in the old Member States (EU-15) and 3-14% in the new Member States (EU-8). But at our country there are major differences between rural and urban areas, the former being marked by a significantly higher poverty level and a correspondingly lower living standard.

Romania ranks 6th in terms of the agricultural area used in the EU countries, with about 13.9 million hectares in 2013, after France, Spain, Great Britain, Germany and Poland – Fig. no.1

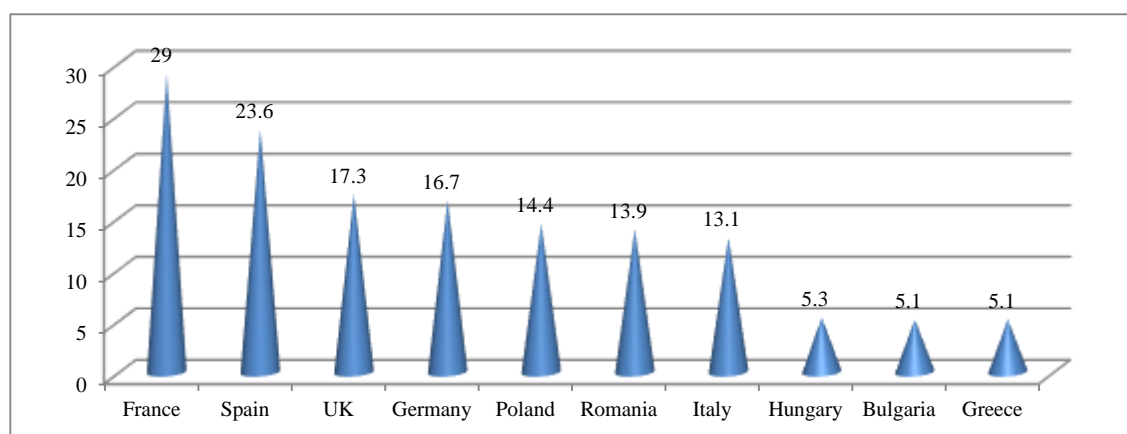


Fig. no.1. Top ten EU countries by agricultural area used (million hectares, 2013)

Source: Eurostat

Of the total agricultural land used, more than half represents cultivated arable land, with an important share of cereal crops. Other uses of the agricultural area used include livestock, pasture, hay, etc.

At EU level, the Common Agricultural Policy (CAP) favors mass production and industrial agriculture, a model to which agricultural systems in Eastern Europe should also rally. There are three versions of modern agriculture in the EU:

- German model, with large farms;
- The model centered on support for small producers;
- A model aimed at coexistence of intensive industrial production in regions that allow this and which can add value to products on world markets, alongside small farms operating in more difficult conditions, but can provide high-quality goods in local markets.

The image of contemporary Romanian agriculture does not fully correspond to any of the above models, being structurally different from the rest of Europe. In fact, Bulgaria and Romania are characterized by a "historic" absence of medium-sized family farms due to the communist tradition and legacy.

Romania suffers from one of the most pronounced structural divisions of agricultural land between all EU Member States and, in particular, from the new Member States. Of the new Member States, Slovenia has the largest percentage of its arable land cultivated by many small farms. Romania, Croatia, Poland, Latvia and Lithuania have relatively evenly distributed land between different categories of farms, but Romania stands out due to the lack of a middle class. Hungary, Estonia, Bulgaria and to a certain extent Slovakia have more than half of their agricultural area cultivated by farms over 100 ha, but all hold a relatively large number of small farms. Instead, the Czech Republic is characterized by the most productive agricultural production oriented to large scale farms.- Fig.no. 2

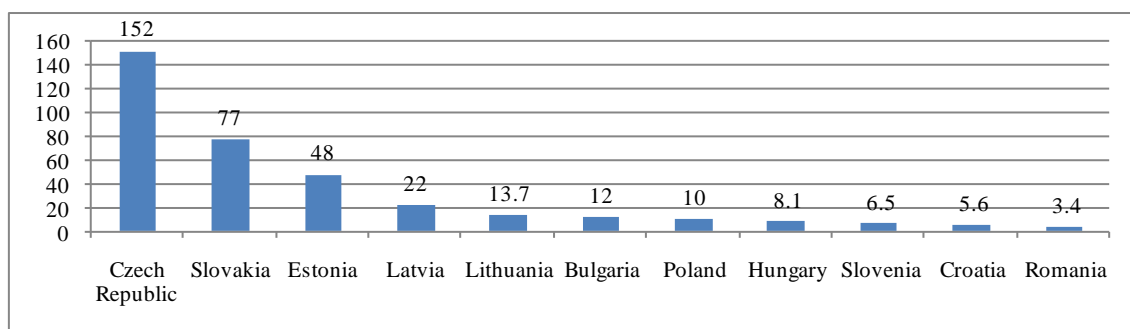


Fig. no.2. Agricultural holdings according to the average size of the farm (hectares)

Source: Eurostat

Romania has certain structural characteristics similar to those of the agricultural sectors of the other EU Member States, but it is unique in terms of the size of the gap between the category of farms and small farms and the prevalence of subsistence / semi-subsistence farming.

As far as the share of the employed population in agriculture is at the level of the European Union, it is around the average of 4.4%, with higher percentages in the countries of Central and Eastern Europe, while in the Western European countries the share of the population in agriculture is below the European average.

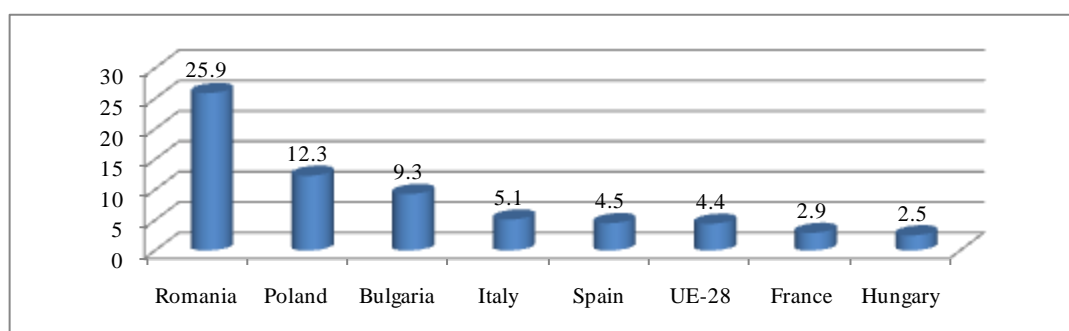


Fig. no.3. Share of the employed population in agriculture (% of the total employed population)

Source: Eurostat

The countries with the largest number of employees in agriculture are the ones with the highest gross added value generated at the worker level. In Romania, however, the vast majority of agricultural workers fall into the category of non-salaried staff (patrons, self-employed workers, unpaid family workers and members of co-operative associations).

All this leads to the fundamental problem facing the Romanian agriculture, namely the low productivity of labor and implicitly the relatively low yield of agricultural production.

In the aftermath of the fall of the communist regime, Romanian agriculture has undergone several changes that can be highlighted by the analysis of the gross added value (VAB) share of the agricultural sector in gross domestic product (GDP).

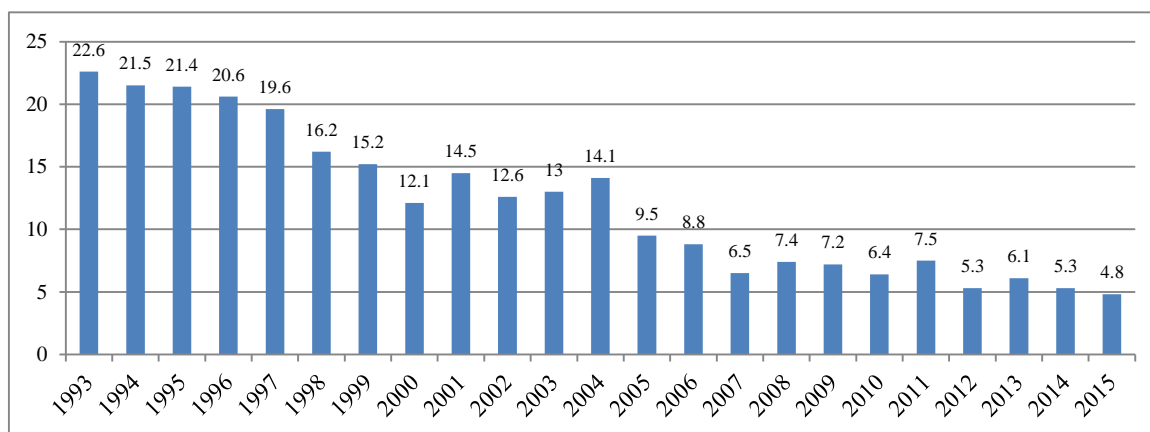


Fig. no. 4. Evolution of VAB share of agriculture in GDP (%)

Source: National Institute of Statistic

Despite the natural agricultural potential of our country, as can be seen from the above figure, the share of the agricultural sector in GDP has suffered considerable reductions over the last two decades. In 1993, the VAB share of the agricultural sector was 22.6% of GDP, and at the end of the analysis period it fell to 4.8%. This development is largely explicable by increasing the importance of industry and the service sector in the national economy as a whole, as well as poor technologies and low labor productivity in the agricultural sector.

Even under current productivity conditions, Romania is one of the main exporters of corn and wheat worldwide, due to the size of the available agricultural area. Thus, our country ranks thirteenth in the top of the world's largest maize producers, finding a net grain exporter. Romania holds the second most favorable position among the world's largest maize producers among EU economies, France being traditionally the largest corn producer in the EU. Romania is at the same time the third player on the Black Sea corn market after Russia and Ukraine.

### 3. Limits and perspectives of the Romanian agricultural sector

Considering the generous agricultural area available to our country, the high land use rate but a reduced share of VAB in GDP, we can deduce that there are a number of limiting factors.

First of all, we can consider the fragmentation of agricultural holdings - Romania suffers from the most serious fragmentation problem in agriculture among all countries of the European Union and has an average holding size similar to Malta or Cyprus, two countries with a very small overall size. Almost 75% of the farms in Romania are under 2 hectares and farms with a size of more than 100 hectares represent only 0.5% of the total, but they exploit 49% of the agricultural area. Here we can take as an example countries with high yields on agricultural production that have concentrated their agricultural potential on farms over 50 hectares - which offers them advantages such as economies of scale, the ability to attract trained farmers, easy access to finance and, implicitly, fast.

Secondly, we must take into account the age and level of training of farmers. The labor force in the Romanian agricultural sector is of an advanced age and an inadequate level of training compared to that of other European countries. This may result in a reluctance to change, to the adoption of new technologies, to innovation. According to the European Commission data, an overwhelming majority of 96.4% of Romanian farmers said they learned their agricultural skills strictly on the basis of practical experience. Another problem characteristic of the Romanian agricultural sector in terms of human resources is the fact that there is no clearly defined professional status of the farmer. This has strong implications for tax and social security and health care.

Another weak point of the Romanian agricultural sector is the low level of capitalization. This modest capitalization can be attributed to a low degree of technology of agricultural holdings in Romania. Less than 2% of holdings in Romania have a tractor - one of the basic technological facilities in the agricultural field, as opposed to 84% of the holdings in the Czech Republic. At the same time, many agricultural holdings are working with already depreciated or bought second-hand machines. The lack of a modern machinery and equipment park is a major obstacle and will not be able to achieve the European average yield without massive investment in state-of-the-art agricultural technology. There is no need to neglect the storage of agricultural products, which in many cases are inappropriate for efficient use.

Another problem facing the Romanian agriculture is tax evasion. The field of agriculture in which this type of tax evasion manifests most strongly is the sale of primary agricultural products, especially cereals and fruit-vegetables, as the producer sells production directly from the field and it reaches the final consumers through intermediaries to a several times higher, and the amounts are not declared.

Agriculture is also strongly affected by the phenomenon of non-legal work, but this is harder to quantify, as subsistence agriculture and unpaid family labor are widely practiced. Many agricultural activities are occasional and they can not be hired by workers with an individual contract of permanent work. These activities need unskilled labor only occasionally at different times of the year and should be done by employing day-laborers. Day workers who work in agriculture are part of the most vulnerable social category and are at the same time beneficiaries of social benefits paid by the state. In many cases, although hiring daytime workers is legally regulated, they refuse to work day by day because they lose the social benefits they receive from the state, so they work without legal forms.

Transforming agriculture and rural areas in a way that makes effective use of available resources requires public action and involvement, along with strategic coordination.

Among the measures to improve the efficiency of the agricultural sector, we mention:

- ✓ *Encourage land merging and stimulate farmers' association.* Although consolidation of farms is a slow process, the integration of small and medium-sized farms into agricultural producer / cooperative groups or organizations may be the safest way to allow access to markets and at the same time to obtain credits for production or investment in facilities common. The difficulty of small farmers, either to reach the market or to obtain market confidence to maximize their income, can be overcome if they understand the benefits and agree to get associative. Consideration should also be given to optimizing the way grants are awarded to small farms;
- ✓ *Decrease of the average age of the population in the agricultural sector and increase of the professional training of farmers,* because a still high agricultural area is used by older farmers (over 65 years old) without professional training. This phenomenon, coupled with a low level of education and training, had a negative impact on the performance of the sector. In the future, it is important to continue encouraging the transfer of agricultural assets between generations through incentives for young farmers together with efforts to increase

knowledge, skills, skills and skill levels. In this case, an important role is played by the education system, which should place greater emphasis on modernizing and diversifying agricultural specializations and harmonizing them with the realities of the agricultural sector in a European context. Young people are more receptive to the association, application of new technologies and environmental issues;

- ✓ *Developing entrepreneurship in rural areas* with the aim of decoupling the activity of these regions from subsistence agriculture. Entrepreneurship is a major factor for economic growth, innovation, competitiveness, employment and social integration. In rural areas there are opportunities for economic diversification through non-agricultural activities, such as rural tourism, which have gained ground in recent years in Romania. The entrepreneurial initiative can support rural actors in identifying and promoting viable strategies and actions that respond to the important economic changes in rural areas as well as to the social needs in rural areas;
- ✓ *Sustainable rural development through the adoption of good practices in EU countries and the formation of rural clusters* that would promote innovation through collaboration between universities, public and private entities. Rural cluster formation can increase the yield of the agricultural sector in the area, but it is mainly a measure of the local economy - because these clusters will not only contain agricultural activities. Promoting modern farm management models would add value to agriculture through rotational or diversification methods, but also through IT or robotics. In fact, the European Commission encourages cluster formation. Thus, in 2016 it developed a typology based on statistical and cluster analysis, according to which Member States are grouped into five categories (clusters), the interpretation of which depends on the importance given to the objectives of the CAP: the sustainability of food production, the sustainable management of natural resources and balanced territorial development. Romania is part of the first group of countries, alongside Austria, Germany, Latvia, Malta and Poland, characterized by internal convergence, flexible implementation of green payments, support for small farmers and sustainable development of rural areas;
- ✓ *Use of environment-friendly agricultural practices and the development of organic farming*. Organic products have a spectacular year-on-year increase across Europe and the world, despite the fact that at this time there is no dominance in the food market. This type of farming could be a niche market for some farmers. In the European Union, countries like Germany, France, Great Britain and Italy represent the most important organic-consuming countries. This phenomenon has expanded also in Romania, which manages to attract more consumers from year to year;
- ✓ *Facilitating access to European and national funds* would contribute to the import of know-how, the renewal of the farm machinery and agricultural machinery, and the modernization of agri-food processing units. These are imperative requirements because the increase in agricultural productivity depends to a large extent on the mechanization of the sector;
- ✓ *Encouraging the cultivation of technical plants* (in, hemp). At present there is an increase in demand for fiber, which can provide an income for growers in areas that are suitable for such crops, but can also represent an alternative to crop rotation and the recovery of the processing sector;
- ✓ *Increase of greenhouse and solarium surfaces*. In this way, the necessary extra-season vegetables can be provided and vegetables can be protected from climate change as a result of global warming;
- ✓ *More efficient promotion of domestic agro-food products on foreign markets*.

By applying the above measures, it is intended to increase the yield in agriculture and increase the volume of exports, which will have a significant impact on GDP and the state budget.

At the same time, we must consider that in order to achieve food security, the European Union claims for implementing food safety management systems, systems that on the one hand help manufacturers achieve safe products, and on the other hand, give traders and consumers the confidence that the products they buy do not endanger their health. (Criveanu, 2012)

That is why, in the future, I believe that every effort must be made to cope with competition on European and agri-food markets, especially through the development of agriculture at European standards.

#### 4. Conclusions

In spite of the considerable agricultural potential of our country, the yields in Romanian agriculture are modest, indicating a utilization of the factors of production far below the optimal values. Properly exploited, the existing potential allows for extra value and employment in a more productive way, thus contributing to real progress towards reducing rural poverty and eliminating income gaps in urban areas.

Romania has to make the most of the favorable global and European trends and its own competitive advantages in the agricultural sector. Romania also needs to maximize the opportunities and benefits it can achieve through the implementation of the CAP and through its participation in the EU and third countries market. At the same time, Romania must manage the main internal constraints and identify the best ways to address some factors such as climate change.

Agriculture and rural development in Romania in the 2030 horizon aims at achieving a level of coherence between agriculture, environment and rural development through the smart and sustainable valorisation of agricultural land, labor and capital.

The Romanian farmer in the 21st century must be competitive, connected to current information, open to innovation and new technologies, reaching the same level of well-being and similar living conditions as the inhabitants of urban areas. In this way, Romania will ensure its food security and become an important player in European and international agri-food trade. At the same time, the competitiveness of agrifood products must be related to the sustainability (sustainability) of their production.

## References

- Albu, L.L. (coord.), *Impactul aderării României la Uniunea Europeană asupra economiei românești. Analiză sectorială*, Studii de strategie și politici SPOS 2017, Studiul nr. 1, IER, (2018)
- Criveanu, I., Sperdea N.M., Criveanu, R.C., *Obtaining Food Safety by Applying HACCP System*, Annals of the University of Petroșani, Economics, 12 (1), pg. 61-68, (2012)
- Nițescu, A., *The Importance Of Clusters In Regional Development*, A XII ediție a Conferinței Internaționale „Dezvoltarea Economico-Socială Durabilă a Euroregiunilor și a Zonelor Transfrontaliere” Academia Română, Filiala Iași- Institutul de Cercetări Economice și Sociale „Gh. Zane Iași, (2016)
- Nițescu, A., *General Aspects on Regional Development*, Annals of the „Constantin Brâncuși” University Târgu Jiu, Economy Series, Editura Academica Brâncuși, nr.5/2015, pag.32-36, (2015)
- \*\*\*, *Strategia pentru dezvoltarea sectorului agroalimentar pe termen mediu și lung orizont 2020-2030*, M.A.D.R., București, (2015)
- \*\*\* [https://ec.europa.eu/agriculture/statistics\\_en](https://ec.europa.eu/agriculture/statistics_en)
- \*\*\* [https://ec.europa.eu/eurostat/statistics-explained/index.php/Farmers\\_in\\_the\\_EU\\_-\\_statistics](https://ec.europa.eu/eurostat/statistics-explained/index.php/Farmers_in_the_EU_-_statistics)

# The Public-Private Partnership in Romania -Theoretical Approaches

Maria Ciurea<sup>a\*</sup>

<sup>a</sup>University of Petrosani, University Street, No. 20, Petrosani, 332006, Romania

---

## Abstract

Along with the new challenges in the process of adapting to the market economy, targeting the demand and supply law, the competition law and the process of Romania's integration into the European Union, the rehabilitation of transport infrastructure, water supply, waste recycling, environmental protection, monitoring state aids, ensuring a loyal and predictable business environment, are the main reasons for using public-private partnership as a way of working together between the public sector, the initiator of public utility projects and the private sector, the fund holder and the executive management. Increasing the availability of the private sector to take on a range of responsibilities and risks as well as the public sector to privatize public utility services has resulted in the multiplication of efforts to introduce the concept of public-private partnership to achieve economic and social objectives and projects from Romania.

Over time, the concept of public-private partnership has been the subject of legislative regulations both in the Member States of the European Union and in Romania, which recently adopted a new normative act on this type of partnership and which constitutes a objective of the Governance Program over the period 2018-2020 on the objectives of economic growth and strengthening fiscal-budgetary sustainability by significantly increasing the budget-financed investments or by accelerating the absorption of the European funds and by stimulating private investment. In view of the above-mentioned aspects, we propose that through this paper we address the theoretical issues of the public-private partnership and from the investigations carried out to highlight the advantages and the limits of a partnership of this kind, but also the main categories of institutions that are most effective in realizing of such partnerships with major benefits for the entire national economy.

**Keywords:** Public - Private Partnerships, Private Sector, Public Sector, Legislation, Policy Management, Benefits and Limits .

---

## 1. Introduction

The Public-Private Partnerships (PPP) is the way in which stakeholders have a common goal of attracting private investment to increase efficiency and deliver high performance public services, based on clearly defined and coordinated rules to achieve the expected results. A public-private partnership is a form of cooperation between the public and the private sector, based on certain regulations on the basis of which such partnerships may arise and which may take the form of: works or service contracts, concession contracts, joint venture contracts, which will bring important benefits to both partners, and the risks and costs are distributed proportionally between them. Although the interests of the partners are different, the private entity is profit-oriented and the public one is aimed at respecting the principles of economy, efficiency and effectiveness in the use of public funds, ultimately the same is the goal of financing, building, renovating, managing or maintaining goods through which they want high quality public services. In doing so, each partner contributes to planning and mobilizing the resources needed to achieve a common goal, each based on a voluntary decision and contributing with its own, material, financial or other resources (Man and Măcriș, 2014).

A public-private partnership is made on the basis of a long-term contract concluded between partners for the purpose of carrying out activities of public interest, based on the capacity of each partner to equitably allocate resources, risks and benefits, being the main opportunity to introduce private management in public services.

The sectors of the economy that are suitable for public-private partnership projects are very diverse, including water, electricity, gas, sewerage, waste treatment, telecommunications, collective restoration, research and development, education, health, tourism, maritime and air transport, justice, defense and others.

---

\* Corresponding author. Tel.: +0-000-000-0000 ; fax: +0-000-000-0000 .  
E-mail address: author@institute.xxx .

Although in Romania there have been and there are various forms of collaboration between public and private entities in various fields, the legal mechanisms of such a partnership have so far not been used with maximum efficiency to achieve the expected results in these sectors, although they would could have been a viable option for financing public or infrastructure services.

## 2. Research methodology

The need for knowledge in this field has led to the investigation of the topic addressed. In order to accomplish this approach, certain principles and rules specific to the research methodology were observed, among which mention: review of the specialized literature, use of other sources of information: respectively: various analyzes and studies elaborated on this topic and the specific legislation in the field. The basis of this paper was the theoretical research on the methodological aspects used in the case of the public private partnership in the context of the new regulations imposed at the level of Romania or at European level, quantitative method, observation, analysis and synthesis. In the context of the new approaches, based on the ideas found in the literature and in the normative framework, a synthesis of the various aspects of the public-private partnership resulted in various opinions with consequences in the evolution and development of the economy.

## 3. Theoretical and legislative approaches to public-private partnership

As a result of the various forms of collaboration between public and private entities, it is rather difficult to formulate a template definition of public-private partnership. Different perception of this type of partnership is due to the existence of various systems of administrative organization and public services encountered in different communities and political cultures. Currently, public-private partnership (PPP) is a notion often present in political speeches and in economic, financial and legal publications, in the economic press, or in international institutions. The notion of public-private partnership is any form of collaboration between the public and the private sector that is legally different from the point of view of the way in which partnerships are expressed and is different from one legal system to another.

In Romania, the emergence of the first public-private partnership structures has been formed at national level since 1990 as a result of developing sectoral, national strategies and institutionalized structures that have been generated by the new challenges emerging in the development and consolidation of the economy the privatization of public utility services, the development of the business environment, which led to an increase in the private sector's willingness to take on a range of responsibilities and risks, the urgent need for local government to find new financing solutions for activities, as well as the process of integration into the European Union (Dima and Man, 2013; Grabara et. al, 2013).

Legislative approaches since the onset of these partnerships to date did not lead to the achievement of outstanding results related to the development of major public-private partnership projects that will contribute substantially to economic development, especially local communities, but also the economy in its whole. For these reasons, but also due to the fact that the concession legislation was incomplete and unclear at that time, it was the main obstacle for the optimum development of PPP projects, and it is necessary to adopt new legal regulations that have succeeded over time.

In this respect, in 2010, through the Public-Private Partnership Law No.178, it was attempted to regulate the way of realizing a PPP project that had as main objective the design, financing, construction, rehabilitation, modernization, operation, maintenance, development and the transfer of a public good or service. Surprisingly, this law did not bring the desired results, as no public-private partnership project was concluded during the period in which it was in force. This law could not be put into practice for *several reasons*, namely:

- ✓ *its unclear formulation;*
- ✓ *the establishment of a legislative parallelism, i.e. its implementation realises when the concessions and public procurement legislation is not applied;*
- ✓ *the rigidity of the regulations in this normative act;*
- ✓ *the lack of an interface in the Electronic Public Procurement System (SEAP) useful in publishing selection ads.*

These issues did not allow the development of PPP projects and the attraction of private funding, as expected with the entry into force. The SEAP functionality became operational only in early 2013 when it was possible to publish selection and PPP contracts.

As our country as a member of the European Union through the commitments assumed had the obligation to ensure the harmonization of the legislative and institutional framework for the development of investment projects under public-private partnership regime, it established by a Government Decision under the subordination of the Ministry of Public Finance, The Central Unit for the Co-ordination of Public-Private Partnership (UCCPPP), having the role of a central institution in the field of public-private partnership projects with tasks of guidance and monitoring of the public partners and of the private investors interested in organizing and carrying out activities a public-private partnership project.

In 2012 at the level of the central public administration a series of reorganizations took place which led to the passing of UCCPPP under the subordination of the Department for Foreign Investments and Public-Private Partnership (DISPPP), a specialized body with legal personality from the Government working apparatus, which functioned until the end of 2016 when it was totally divided by a new legislative act and its activities were taken over by the Ministry of



Public Finance. Although the law has been altered by the European Commission's observations on non-compliance with principles governing public contracts, it has proved to be a regulation that can not be adapted to the economic and legal realities of the moment.

Regarding the fact that the law adopted in 2010 proved to be inoperable, in May 2018, the Government adopted the Government Emergency Ordinance No. 39 on public-private partnership, which is one of the objectives of the Governance Program for the period 2018-2020, with on the objectives of economic growth and strengthening fiscal-budgetary sustainability by significantly increasing the investments financed from the budget or by accelerating the absorption of European funds, as well as by stimulating private investments. Thus, through macroeconomic fiscal-monetary policies, macroeconomic consolidation can be achieved and, against the backdrop of macroeconomic equilibrium, wealth growth will be achieved. In this respect, it is proposed to stimulate private investment through active involvement of the state, i.e. by enhancing the projects in public private partnership and by state aids granted by the Government.

According to this regulation, the public-private partnership aims at the realization, rehabilitation, extension of a good or property belonging to the patrimony of the public partner and/or the operation of a public service. Its provisions are operable by the public partner for the implementation of a project if the project substantiation study demonstrates, in addition to the elements presented in Table 1, that more than half of the revenues to be achieved to the project company from using the good/goods or operating the public service that is the object of the project come from payments made by the public partner or by other public entities for the benefit of the public partner.

Table no.1. Key elements of the fundamentering study

No. crt.	Elements
1.	The project financing
2.	The economic efficiency of the project
3.	The risk distribution structure for each alternative project implementation option
4.	The degree of support of the project and the comparison of alternative contractual options/arrangements for project implementation
5.	The characterization of the project in relation to the public deficit and public debt, calculated according to the methodology applicable under the European Union law

Also, **the mechanism of public-private partnership** is characterized by a *series of elements*, among which (EIB, 2017):

- *cooperation between the public partner and the private partner for the implementation of a public project;*
- *financing the project, mainly from private funds and depending on the situation, by pooling private funds with public funds;*
- *the relatively long duration of contractual relationships over 5 years, allowing the private partner to recover the investment and achieve a reasonable profit;*
- *distributing the risks between the public partner and the private partner, depending on each contracting party's ability to assess, manage and control a particular risk;*
- *achieving the goal pursued by the public partner and the private partner.*

The following **forms** are known within this partnership (The Government of Romania, O.G. 39/2018):

✓ *institutional public-private partnership* - is the one made under a contract between the public partner and the private partner, through which the two partners form a new company that will act as a project company and which, after being registered in the company register, acquires the capacity as a party to the respective public-private partnership contract;

✓ *contractual public-private partnership* - is based on a contract between the public partner, the private partner and a new company whose share capital is wholly owned by the private partner acting as a project company.

All public-private partnership contracts may also be concluded for the purpose of performing relevant activities in the public utility sectors provided by Law no. 99/2016 regarding the sector acquisitions, as subsequently amended and completed, as well as for the realization by a private operator of the community utilities services provided by the Community Public Utilities Act no. 51/2006, as subsequently amended and supplemented.

Regarding the **financing of investments under public-private partnership contracts**, this is carried out as follows:

- *in full, from financial resources provided by the private partner;*
- *from the financial resources provided by the private partner, together with the public partner.*

The private partner provides the necessary financing for the realization of the investments from own resources and/or attracted resources from the donors and the public partner can contribute to the financing of investments with public financial resources, including from external non-reimbursable post-accession funds and from the national contribution related to them the conditions laid down by national and European Union legislation. The contribution of the public partner to the financing of investment in a public-private partnership contract made up of financial resources other than non-reimbursable external funds and the national contribution to such funds may not exceed 25% of the total amount of the investment.

In table no. 2 the mandatory steps to be taken to conclude and commence the fulfillment of the obligations of a public-private partnership contract are to be presented.

Table no. 2. Stages covered in a public-private partnership contract.

No. crt.	Steps
1.	Making a fundamenting study by the public partner.
2.	Approval of the Government's substantiation study for central public administration projects or, where appropriate, deliberative authorities for local government projects.
3.	Examining the procedure for awarding the public-private partnership contract.
4.	Approval of the public-private partnership contract resulting from the finalization of the negotiations and initiated by the parties, by the Government for the central public administration projects or, as the case may be, by the deliberative authorities for local public administration projects.
5.	Signing the public-private partnership contract.
6.	Fulfillment of all the conditions of suspension provided for in the public-private partnership contract, including the financial closure.

Public entities wishing to carry out public-private partnership projects will organize and operate by decision of the head of the public entity, internal units for the coordination of public-private partnership projects organized as internal structures without legal personality dedicated to the preparation, assignment and implementation of the public-private partnership contracts or, as the case may be, the implementation of the contracts assigned by the National Commission for Strategy and Prognosis, which will be supported in carrying out the activity of technical, financial and legal consultants contracted in accordance with the legal provisions.

#### 4. Considerations on the benefits and limits of a public-private partnership

Analysing the literature on this topic, we found that the institutional capacity to create, manage and evaluate public-private partnerships is essential to ensure that they become an effective tool for delivering important services such as infrastructure, which is best suited to such partnerships. Many economic analysts, especially Europeans, that pay more attention to public-private partnerships, consider that transferring management and private sector knowledge to the public sector can reduce the management gap in the public sector resulting from the fact that people who manage public resources, are not theirs, they do not assume any risk, often in conflict of interests or may be subjected to external influences or pressures, affecting the observance of the principles of economy, efficiency and effectiveness in the use of public funds.

Over time, the implementation of PPP projects has highlighted a number of *benefits* that refer to (Moldovan, 2017; Petrescu, 2010; Vertakovaa and Plotnikov, 2014):

- ✓ *better implementation of public projects from the point of view of observance of the execution terms and the fitting into the approved budgets;*
- ✓ *the allocation of financing costs both during construction and operation, with the effect of reducing immediate pressures on public sector budgets;*
- ✓ *providing easy facilities to attract additional resources in a specific area;*
- ✓ *reducing construction costs and improving quality by capitalizing on the efficiency and innovative potential of the private sector;*
- ✓ *ensuring attracted stakeholders to support all project-specific actions.*
- ✓ *stimulating research - development, innovation and sustainable development efforts;*
- ✓ *introducing new, more efficient and effective ways of achieving projects;*
- ✓ *the proper allocation of risks between the public and private sectors, resulting in a reduction in the overall costs of the project.*

Since public - private partnerships have a common goal in their creation and development, advantages have been identified by both parties, and they will be described in Table 3. As can be seen from the information below, the public sector is most helpful in implementing such partnerships.

At the same time, as for any other activity, also in the case of public - private partnerships, certain *limits* have been identified that cover a number of aspects (European Court of Auditors, 2018; Jomo et al., 2016):

- *responsibility and transparency in the provision of services is limited by the involvement of a private partner to whom the same obligations as the public are not subject.*
- *long-term partnerships may involve higher costs if the project is funded by the private partner through a private loan, with the risk of rising final costs;*
- *the existence of high transaction costs in the negotiation procedures, the financing needs being relatively large and the association agreements being carried out over fairly long periods. In such a situation, only a relatively small number of private or non-governmental partners will have the financial and institutional capacity to enter into such partnerships that will distort economic activity and will create competitive advantages only for a part of the economic partners.*

▪ *both partners must have the skills and capacities specific to such partnerships in order for a contract to be successfully assigned and implemented and the number of partners with such capabilities is rather limited.*

Table no. 3. Advantages of partnerships by sectors

Crt. no.	Public sector	Private sector
1.	Attracting private financial resources to finance public works or services.	Public Private Partnership is an excellent business opportunity for the private sector.
2.	Cost reduction.	It benefits from intellectual property acquired through the partnership project.
3.	Transferring a part of the project risks to the private partner or the risk of emergence of force majeure.	Project funding can be done not only from private funds, but can also include a component of public funds coming from non-reimbursable funds and the corresponding national co-financing.
4.	Increase efficiency of public projects by using know-how and private management in public projects.	-
5.	Less implementation time.	-
6.	Increased quality of public services provided to the population.	-
7.	The possibility of benefiting at the end of the project from the property right of the product made under the partnership contract, which is transferred free of charge and free of any tasks to the public partner.	-

According to the legal provisions and the literature (Pîrvu and Voicu Olteanu, 2009; Munteanu et.al, 2013), the **risks** of financing, obtaining permits, opinions, timely delivery of projects or activities are distributed between the two equitable partners, depending on their possibilities and expertise to deal with them, being generated by:

✓ *the absence of common goals and objectives for the partners involved in this form of collaboration can end up conflicts both during the project implementation and in the operational phase with negative consequences on the fulfillment of established indicators;*

✓ *the impact of the project on other services or projects, such as public transport-related transport infrastructure projects;*

✓ *the existence of differences in organizational culture between partners, accentuated in the event of difficulties during the project's realization;*

✓ *the lack of coherent national strategies on infrastructure development, a situation that does not allow for the correct estimation of the initial parameters of the project;*

✓ *the existence of a hostile economic and political environment that makes cooperation between partners unattractive.*

Public authorities in Romania consider that it is more profitable to finance public investment by accessing resources through the European Regional Development Fund than through PPP, with the exception of infrastructure investments where the concession's benefits may be higher compared to investments in other areas of public interest activity. Therefore, Romania's delay in implementing PPP projects may be motivated by inadequate legislation in this area and the lack of experience of the public authorities that should initiate these projects and the difficulty of completing them.

## 5. Conclusions

The utility of public-private partnership has proven its effectiveness in socially important areas such as education, health, services and transport systems development. These types of partnerships have an important growth in Europe, but with macroeconomic and systemic significance only in the UK, Turkey, Italy, France, Germany, Portugal, the Netherlands and Spain. In all other European countries, including Romania, the importance of investments through such partnerships remains low compared to traditional public investment procurement. For the Romanian public sector a particularly important aspect is the necessity of satisfying the public interest through appropriate public services as the main means of eliminating or reducing the factors of stagnation of the evolution of this sector and satisfying the social needs whose diversification requires finding new forms to provide public services through the public-private partnership, whose specificity is given by private intervention in public administration, under the control of public authorities. So we need a modern and flexible public administration that can manage the priority of public investment for development, which includes as a tool to implement these partnerships, which would prove useful for making public investments especially in rural areas, which increase the competitiveness of land use and improve the quality of life of the inhabitants.

Public-private partnerships are often accompanied by significant deficiencies in policy management and partnership implementation, as there is no interest in developing and promoting strategic priorities as well as in respecting important principles and criteria through a co-ordinated and cooperative system among all partners, and due to the fact that the legal framework is not clear and explicit for all situations that may arise, and no tools for effective management of these projects are developed.

The implementation of many public-private partnership contracts, with no performing results in favour of the people and public partner benefits, with the recovery of private-sector investment, is the result of an institutional framework with weaknesses in evaluating, monitoring, analysing, recording and reporting such contracts, generating inefficient functionality of the system.

Research has shown that these partnerships are more suited to economic infrastructures such as transport and electricity, where demand is relatively stable, and the impact on service quality is easy to assess and where better quality infrastructure can reduce costs at the stage operational. For public - private partnerships to become an effective tool for financing key infrastructure projects, our country needs to have the institutional capacity to create, manage and evaluate these partnerships.

## References

- Dima, I.C., Man, M., Considerations on the strategy for sustainable development of companies under the conditions of current globalization, *Science Series Data Report*, vol. 5, nr. 5, pp. 66-75, (2013).
- Grabara, J., Man, M., Kot, S., Costs Incurred by Designing and Implementing the Logistical Projects in the Activity of Companies, *Applied Mechanics and Materials*, vol. 309, pp. 221-228, Trans Tech Publications, (2013).
- Jomo, K.S., Chowdhury, A., Sharma, K., Platz, D., *Public-Private Partnerships and the 2030 Agenda for Sustainable Development: Fit for purpose?*, Department of Economic & Social Affairs, DESA Working Paper No. 148 ST/ESA/2016/DWP/148, February (2016).
- Man, M., Măcriș, M., Analysis of the SMEs Development in Romania in the Current European Context Affected by the Global Economic Crisis, *Procedia Economics and Finance*, vol.15, pp. 663-770, (2014).
- Man, M., Măcriș, M., Analysis of Implementing an Operational Programme Financed from Structural Instruments. Case Study – Romania, *International Journal of Business Management and Economic Research (IJBMER)*, Vol 5(1), pp. 9 – 15, (2014).
- Moldovan, O., Public-Private Partnership in Romania: A Missed Opportunity, *Revista Transilvană de Științe Administrative*, 1(40), pp. 60-77, (2017).
- Munteanu, V., Stănescu, G.S., Boca Rakos, I.S., The Degree of Reporting of the Environmental Information by the Economic Entities in Romania, *International Journal of Academic Research in Accounting, Finance and Management Sciences*, Vol. 3, No.2, pp. 78–83, (2013).
- Pârvu, D., Voicu Olteanu, C., Advantages and Limitations of the Public Private Partnerships and the Possibility of Using Them in Romania, *Transylvanian Review of Administrative Sciences*, 27E, pp.189-198, (2009).
- Petrescu, M., Argumente în vederea implementării parteneriatului public privat (PPP), *Revista de finanțe publice și contabilitate*, nr/4, pp.52-54, (2010).
- Vertakovaa, J., Plotnikov, V., Public-Private Partnerships and the Specifics of Their Implementation in Vocational Education, 21st International Economic Conference 2014, IECS 2014, 16-17 May 2014, Sibiu, Romania, *Procedia Economics and Finance*, vol. 16, pp. 24 – 33, (2014).
- Curtea de Conturi Europeană, *Raport special privind Parteneriatele public-privat în UE: deficiențe generalizate și beneficii limitate*, nr.9, 2018, <https://www.eca.europa.eu/ro/Pages/DocItem.aspx?did=45153> (Accessed on 21.08.2018).
- EIB Group Survey on Investment and Investment Finance 2017 Country overview: Romania, [http://www.eib.org/attachments/efs/eibis\\_2017\\_romania\\_en.pdf](http://www.eib.org/attachments/efs/eibis_2017_romania_en.pdf) (Accessed on 28.08.2018.)
- Guvernul României, *Ordonanța de urgență nr.39/2018 privind parteneriatul public-privat*, [nap.gov.ro/web/wp-content/uploads/2018/06/ORDONANȚĂ-DE-URGENTĂ-Nr.-39-2018-în-vigoare-din-data-de-10-mai-2018.pdf](http://nap.gov.ro/web/wp-content/uploads/2018/06/ORDONANȚĂ-DE-URGENTĂ-Nr.-39-2018-în-vigoare-din-data-de-10-mai-2018.pdf), (Accessed on 25.08.2018).

# Considerations on the Need to Implement International Accounting Standards for the Public Sector in Romania

Maria Ciurea<sup>a\*</sup>

<sup>a</sup>University of Petrosani, University Street, No. 20, Petrosani, 332006, Romania

---

## Abstract

The current context of the globalization of the economy, the development of the capital markets and the accession of Romania to the European Union, imposed a series of measures regarding the introduction of accrual accounting in order to fulfil the assumed commitments. Therefore, Romania's primary purpose in developing the public accounting system was to harmonize it with national legislation, European directives and International Accounting Standards for the Public Sector. From the analysis carried out on the reform initiated in the Romanian public accounting system, it transpired that the national legislation was substantially improved by introducing specific elements for the accrual accounting. Regarding these aspects, the objective of this paper is to undertake an analysis of the implementation of the International Public Sector Accounting Standards by identifying those standards that can be easily applied and adapted to the specifics of the public system in Romania, given that the regulatory bodies recommended their application rather than their obligation.

*Keywords:* International Public Sector Accounting Standards (IPSAS), accounting harmonization, implementation.

---

## 1. Introduction

Accounting harmonization has made it necessary to adopt a common financial reporting language, which is achieved through the accounting normalization process. In this respect, the improvement and reduction of the differences between the national accounting practices and the international ones, aiming to develop principles and norms of a general nature leading to comparability of the information provided by the content of the financial statements of entities in the public sector. At the same time, the harmonization of rules is seen as the main means of ensuring the transparency and comparability of the information that leads to the optimization of the public sector decision-making process, from which interested parties can make an appreciation of the performance of different levels of this system. At international level, accounting harmonization at the public system level is guided by the International Public Sector Accounting Standards (IPSAS) developed by the International Public Sector Accounting Standards Board (IPSASB), a body that aims to evolve accounting standards to the highest levels, so that they can be used efficiently by public entities in the process of generating financial statements with a general purpose, which will lead to an improvement in their degree of trust and transparency. Thus, there are concerns both at the international level and within the European Union for the normalization and harmonization of accounting systems in order to create uniform procedures for the recording of financial transactions at the level of all states (Bellanca, 2015).

The integration of Romania as a full-fledged member of the European Union has led to multiple changes in the level of accounting for public institutions. In this regard, the accounting regulations for public institutions, approved by O.M.F.P. no. 2021/2013 are based on the international vision of public sector accounting and professional judgment. From this perspective, these regulations explicitly or implicitly include elements of the International Public Sector Accounting Standards (IPSAS).

Government adoption of IPSASs will improve both the quality and comparability of financial information reported by public sector entities around the world. It will also strengthen the management of public finances, which will lead to a better assessment of government resource allocation decisions, thereby increasing transparency and accountability (Tudor and Crişan, 2017; Dascălu et. al., 2006; Nistor, 2017; Ristea et.al., 2010).

---

\* Corresponding author. Tel.: +0-000-000-0000 ; fax: +0-000-000-0000 .  
E-mail address: author@institute.xxx .

In the current context at the European level, it is envisaged to develop a harmonized accounting framework that responds to the specific needs of the public sector in the Member States. From this perspective, the European Commission develops its own accounting rules, called the European Public Sector Accounting Standards (EPSAS), based on IPSAS. Given that Romania is a member of the European Union, it will have to comply with the European public accounting requirements as well. That is why accountants working in public institutions need to familiarize themselves with IPSAS specific accounting concepts and reasoning.

## **2. Legislative approaches regarding the evolution of public accounting in Romania in view of the transition to the adoption of IPSAS**

Over time, our country's public accounting system has evolved in light of the changes that have taken place at certain times. All this was determined by the emergence of the market economy and the fall of the communist regime. A number of legal provisions constituted the cornerstone that revolutionized public accounting in Romania, namely: Accounting Law no. 82/1991, Order of the Ministry of Public Finance (OMFP) no. 1746/2002 and 1792/2002 on the hiring, liquidation, authorization and payment of expenses to public entities, GD no. 81/2003 and OMFP no. 1487/2003 regarding the revaluation and amortization of fixed assets held by public entities, OMFP no. 520/2003 on the organization and management of the budgetary revenues, but not the last of the OMFP no. 1917/2005 regarding the new plan of accounts for public institutions, which made a closer alignment to the entity's chart of economic accounts.

The adoption of IPSASs started in 2002, when the transition from the cash accounting to the accrual - based accounting took place, having as a legal document the implementation of OMFP no. 1746/2002, through which the methodology for organizing and managing the accounting of the public system, the chart of accounts and the accounting monographs used for the registration of operations was established. The basis for this regulation was a series of elements of the European System of Accounts (ESA 95), the Financial Regulation of the Council of Europe no. 1605/2002 or the Manual of Government Financial Statistics, prepared by the International Monetary Fund.

Also, the introduction of the new budget classification applicable from January 2006 through OMFP no. 1954/2005 was imposed by the necessity of its correlation with the National Accounts System and the 2001 Public Finance Statistics Handbook. The purpose of this order was to comply with the Standards of International Bodies on the Compilation and Presentation of Public Finance Statistics, in order to improve the structure and the transparency of operations carried out on public funds as well as our country's commitment to implementing the *acquis communautaire* in the field of public finances.

Later, after Romania's accession to the European Union, it was necessary to improve accounting in the public system through the emergence of new regulations at the national level through OMFP no. 2021/2013, applicable on 1 January 2014, and at European Union level by Regulation no. 549/2013 on the European System of National and Regional Accounts of the EU (SEC 2010) applicable on 1 September 2014, the date from which information was transmitted to Eurostat in compliance with the 2010 ESA rules. This sets out the accounting framework applicable at European level which gives the possibility of an analytical and systematic presentation of a country's economy, its main components and its relations with other economies in order to ensure international comparability, harmonization with other economic and social statistical systems, consistency, stability over a long period, focus on process description economically sound and easy to monitor; application capability in different situations and with different purposes. Consequently, the transposition of this regulation at the level of Romania was achieved through: OMFP no. 496/2014 for the approval of the Methodological Norms regarding the acquisition and withdrawal of the certificate of attestation of acquired knowledge in the field of the European System of Accounts and of the Law no. 270 / 2013 amending and supplementing Law no. 500 / 2002 on public finances.

Therefore, the progress made in our country's public accounting system for the implementation of IPSASs contributes to: the increase of the quality of financial reporting by the institutions, the credibility and transparency of the information provided, the achievement of comparability and a responsible evaluation at the level of all the managed resources, making accurate decisions, assessing the financial situation, financial performance and cash flows, good management and resource management, more detailed information on cost-effective management of results, performing more effective internal control and much more transparency regarding assets and liabilities (Deaconu et. al., 2011; Gisberto and Nisulescu-Ashrafzadeh, 2017).

All these aspects covered by public accounting have been and are still possible following the evolution of the national regulatory framework, with IPSASs main benchmark setting out how to recognize, evaluate, describe and present transaction information and events in general purpose financial statements.

## **3. The Current State of Implementation of the International Public Sector Accounting Standards**

The world globalized economy and financial markets have contributed to the recognition of IPSAS as a common methodological basis for the preparation of financial reporting by the budgetary sector. The experience of other countries reflects that such features, such as intelligibility, relevance and comparability of information, are achieved through the direct use of international standards for the preparation and reporting of financial statements (Măcriș, 2015). At the public sector level, by introducing accrual accounting and waiving cash accounting was the first step and the

most important reform process of public financial management. On this basis, IPSASs are the main international reference that provides financial information to the public sector through the use of accrual accounting. International bodies contributed by adopting IPSASs to their legitimacy, this ample process having a particular impact on their implementation at the EU level for the Member States. The accounting harmonization imposed the need to adopt a common financial reporting language, which can be achieved through the accounting normalization process. In this regard, the improvement and reduction of the differences between the national accounting practices and the international ones, aiming to develop principles and norms of a general nature leading to comparability of the information provided by the content of the financial statements of entities in the public sector (Man and Ciurea, 2016 a, b). At the same time, the harmonization of rules is also considered as the main means of improving clarity and comparability, which will also lead to the completion of the wide public decision-making process, from which stakeholders can assess the performance of the different levels of this system. Public Accountancy Harmonization (IPSAS) has as its main reference the International Public Sector Accounting Standards (IPSAS).

The accrual-based accounting standards adopted for all areas of the public system at EU level are the best solution for public sector management and governance. In the public sector, accrual accounting is intended to increase the efficiency and effectiveness of the business, while providing liquidity requirements for optimal performance of this system (Pitulice, 2013; Tudor, 2010). In this context, IPSASs are the only tool for accounting for the public system that helps to manage it, according to clearly defined principles, which largely depend on information from managers providing information on the financial and economic situation and performance of it. This type of accounting is the only system for obtaining generally accepted information, which identifies the true, complete and reliable image of the financial situation and the performance of public entities (Nicula and Bragadireanu, 2017; Dumitru and Pitulice, 2014; Munteanu et. al., 2014). At the same time, this implies the recording of all transactions, not when cash is made, but at the moment when the economic value is created at the time when claims and obligations arise or turn out or when they record transactions when the amount is received or paid. In fact, accrual accounting can be considered as complementary to cash accounting and not an alternative to it.

Since 2012, C.E. through EUROSTAT initiated the process of setting up the European Public Sector Accounting Standards (EPSAS), which considered the fact that the implementation of the central EU budget made up of national budgets, requires common accounting tools to be harmonized and applied by all members. Therefore, IPSASs are the most appropriate reference framework for the future development of these European standards, called "EPSAS", whose adoption contributes to the broad process of meeting EU requirements, and will bring substantial benefits better governance, development of public management, accountability in financial management and transparency.

Based on the latest information made by visiting [www.ifac.org](http://www.ifac.org), in the section for the public sector, we have found that new standards have been added, currently there are 41, of which 40 for accrual accounting and one for house accounting. Their inspiration came from IFRS and some of them have been tailored to the public sector. In this respect, the following standards may be mentioned: IPSAS 22 "Presentation of Financial Statements to the State Sector", IPSAS 23 "Income from Transactions other than Exchange Rate (Taxes and Duties)", IPSAS 24 "Presentation of Budget Information in the Financial Statements", IPSAS 32 "Service Concession Liabilities: Grantors", IPSAS 33 "First-time Adoption of the Undertaking Basis", IPSAS 39 "Employee Benefits", and IPSAS Standard "Financial Reporting according to Cash Accounting". Starting from the fact that the evolution and context of the act of the public sector activity is constantly changing, these standards are regularly amended and revised.

At the level of Romania, the institution with attributions in the field of public accounting regulations is the Ministry of Public Finance (MFF), which through the General Direction of Treasury and Public Accounting has as main duties:

- *studying and analyzing the European Directives, the International Standards and the Financial Reporting of the Public Sector, as well as other documents adopted by the professional bodies in order to achieve the convergence of these regulations with the national ones;*
- *ensuring that the annual and quarterly financial records required to provide information for the statistical reporting of EUROSTAT and other international bodies are improved and updated.*

The analysis of the specialized literature on the implementation of IPSASs in our country revealed that the opportunity for cooperation between the Court of Accounts and the Ministry of Public Finance was required to obtain certain assurances that all consolidated accounting reports are adjusted and meet the IPSAS requirements. Thus, in order to respond promptly to the international commitments assumed, this institution carried out a documentation that aimed at the evaluation and the stage of implementation of IPSASs. In this regard, a number of issues have emerged, related to the fact that:

- ✓ *did not exist at M.F.P. any collaboration with another specialized structure regarding the implementation of IPSASs;*
- ✓ *at the level of Romania, an interdepartmental committee was not established for the implementation of IPSAS, although it was adopted in 2017, Order no. 928 on the approval of the Organization and Functioning Regulation of the Public Accountancy Council, it should have been the main independent supervisory body to ensure the convergence of national regulations and practices in the field of public accounting with the regulations applied at the E.U.;*
- ✓ *no implementation timetable for IPSASs was established because it was not a request from the European Commission (E.C.), although the International Monetary Fund and the World Bank requested information on their applicability;*



✓ the completion of the transposition process of all IPSASs has not been accomplished as new developments of the E.C. are expected;

✓ the following standards have been implemented only partially: IPSAS 1 "Presentation of Financial Statements", IPSAS 2 "Cash Flow Statements", IPSAS 4 "The Effects of Changes in Foreign Exchange Rates" IPSAS 5 "Borrowing Costs", IPSAS 11 "Construction Contracts", IPSAS 12 "Inventories", IPSAS 13 "Leases", IPSAS 17 "Property, Plant and Equipment", IPSAS 19 "Provisions, Contingent Liabilities and Contingent Assets", IPSAS 23, "Transactions other than exchange transactions (taxes and charges)", IPSAS 24 "Presentation of Budget Information in Financial Statements", IPSAS 31 "Intangible Assets".

Table no.1. The current state of implementation of IPSASs in the Romanian public system

Crt. nr.	Name of standards	Full implemen- tation	Partial implemen- tation	Non- implementation
1.	IPSAS 1 „Presentation of Financial Statements”	-	X	-
2.	IPSAS 2 „Cash Flow Statements”	-	X	-
3.	IPSAS 3 „Accounting Policies, Changes in Accounting Estimates and Errors”	-	X	-
4.	IPSAS 4 „The Effects of Changes in Foreign Exchange”	-	X	-
5.	IPSAS 5 „Borrowing Costs”	-	X	-
6.	IPSAS 6 „Consolidated and Separate Financial Statements”	-	X	-
7.	IPSAS 7 „Investments in Associates”	-	X	-
8.	IPSAS 8 „Interests in Joint Ventures”	-	-	X
9.	IPSAS 9 „Revenue from Exchange Transactions”	-	X	-
10.	IPSAS 10 „Financial Reporting in Hyperinflationary Economies”	-	-	X
11.	IPSAS 11 „Construction Contracts”	-	-	X
12.	IPSAS 12 „Inventories”	-	X	-
13.	IPSAS 13 „Leases”	-	X	-
14.	IPSAS 14 „Events After the Reporting Date”	-	X	-
15.	IPSAS 15 „Financial Instruments: Disclosure and Presentation”(superseded by IPSAS 28 and IPSAS 30)	-	X	-
16.	IPSAS 16 „Investment Property”	-	-	X
17.	IPSAS 17 „Property, Plant and Equipment”	-	X	-
18.	IPSAS 18 „Segment Reporting”	-	-	X
19.	IPSAS 19 „Provisions, Contingent Liabilities and Contingent Assets”	-	X	-
20.	IPSAS 20 „Related Party Disclosures”	-	-	X
21.	IPSAS 21 „Impairment of Non-Cash-Generating Assets”	-	X	-
22.	IPSAS 22 „Disclosure of Financial Information About the General Government Sector”	-	X	-
23.	IPSAS 23 „Revenue from Non-Exchange Transactions (Taxes and Transfers)”	-	X	-
24.	IPSAS 24 „Presentation of Budget Information in Financial Statements”	-	X	-
25.	IPSAS 25 „Employee Benefits”	-	X	-
26.	IPSAS 26 „Impairment of Cash-Generating Assets”	-	X	-
27.	IPSAS 27 „Agriculture”	-	-	X
28.	IPSAS 28 „Financial Instruments: Presentation”	-	X	-
29.	IPSAS 29 „Financial Instruments: Recognition and Measurement ”	-	X	-
30.	IPSAS 30 „Financial Instruments: Disclosures”	-	X	-
31.	IPSAS 31 „Intangible Assets”	-	X	-
32.	IPSAS 32 „Service Concession Arrangements: Grantor”	-	-	X
33.	IPSAS 33 „First-time Adoption of Accrual Basis IPSASs”	-	-	X
34.	IPSAS 34 „Separate Financial Statements”	-	X	-
35.	IPSAS 35 „Consolidated Financial Statements”	-	-	X
36.	IPSAS 36 „Investments in Associates and Joint Ventures” which has replaced IPSAS 7 and IPSAS 8	-	-	X
37.	IPSAS 37 „Joint Arrangements”	-	-	X
38.	IPSAS 38 „Disclosure of Interests in Other Entities”	-	-	X
39.	IPSAS 39 „Employee Benefits” which has replaced IPSAS 25 with application since 1.01.2018	-	X	-
40.	IPSAS 40 „Public Sector Combinations,” to be implemented with 1.01.2019	-	-	X
41.	IPSAS „Released to Improve Financial Instruments Reporting”	-	-	X
	<b>TOTAL STANDARDS = 41</b>	<b>0</b>	<b>26</b>	<b>15</b>

Also, there are standards that are not found in the Romanian regulations at all, it is the case with the following standards: IPSAS 11 "Construction Contracts", IPSAS 16 "Real Estate Investment", IPSAS 27 "Agriculture" and IPSAS 32, "Commitments concession of services: concessionaires", etc. In the table no.1. the present situation of the implementation of IPSASs in the accounting of the Romanian public system is presented.

From the analysis of the information presented above, it resulted that 29 standards were partially implemented and 12 of them were not implemented at all. Thus, it can be estimated that the implementation rate is 63.4% at the level of 2018. If we refer to the grouping of these standards used to present the financial statements, revenues, expenditures and financial position, we will find that the highest degree of implementation have those relating to the presentation of financial statements, followed by income and expenses.

#### 4. Conclusions

The global financial community, and in particular the European one, agree with the need to implement consistent, high-quality, high-quality counterparts. The need for a common language at the international level in the context of contradiction is very important because it provides a horizon for the professional debate. As a result of the changes in the Romanian public contingency, especially since 2016, when the approved regulations contain concepts and definitions from the International Standards for Public Sector Compatibility. They also recommend the possibility of selecting a contradictory tract to the application of a stable policy through professional judgment correlated with the requirements of the norms. All standards are an indisputable reference for the establishment of new EU-wide public sector accounts.

The conclusion drawn from this analysis is that the implementation of IPSASs is a process that has been successfully launched in only one EU member state, namely Spain, and in other countries this process has been difficult to achieve because of the very large differences between IPSASs and nationally applied standards. Many of the obstacles to the implementation process have been generated by high costs or the need for substantial legislative changes. In Romania, the implementation of IPSASs has been achieved only partially, and the legal regulations in force at national level have and have inspired these standards, but without direct reference to them.

Increasing the efficiency of public administration activity in administrative transparency, the use of modern communication tools and the transmission of information are major objectives that are permanently found in their strategies. One of the tools to implement these goals is to use the FOREXEBUG system that allows for standardizing the reporting and transmission of 15 types of financial statements for each public administration entity versus 43 physical forms that were completed before using the new system. These situations are transmitted in electronic, standardized and secure format, which has allowed the confidence of data collected through cross-checks with system data to be increased. Therefore, the major advantage of using this system is that it allows for electronic monitoring and control of legal and budgetary commitments, with a direct impact on improving financial discipline and preventing the build-up of public institution arrears.

#### References

- Bellanca, S., Cultrera, L., Vermeylen, G., Analysis of Public Accounting Systems in the European Union, *Research in World Economy*, Vol. 6(3), pp.23-35, (2015).
- Deaconu, A., Nistor, S. C., Filip, C., The Impact of Accrual Accounting on Public Sector Management: An Exploratory Study for Romania, *Transilvanian Review of Administrative Sciences*, No. 32E, pp. 74-97, (2011).
- Dascălu, C., Nişulescu, I., Caraiani, C., Ştefănescu, A., Pitulice, C., *Convergenţa contabilităţii publice din România la Standardele Internaţionale de Contabilitate pentru Sectorul Public*, Editura CECCAR, Bucureşti, (2006).
- Dumitru, M., Pitulice, I. C., Ştefănescu, A., *Cartea verde a contabilităţii instituţiilor publice, Ediţia a II-a*, Editura RENTROP & STRATON, Bucureşti, (2014).
- Gisberto A., Nisulescu-Ashrafzadeh I., *Contabilitatea în instituţiile publice*, Editura ASE, Bucureşti, (2017).
- Ilie, D., Alecu, G., Convergenţa contabilităţii publice cu Standardele Internaţionale de Contabilitate pentru sectorul public (IPSAS), *Revista Audit financiar*, No.10, (2011).
- Măcriş, M., *Contabilitatea instituţiilor publice*, Editura Universitas, Petrosani, (2015).
- Man, M., Ciurea, M., Transparency of Accounting Information in Achieving Good Corporate Governance. True View and Fair Value, *Social Sciences and Education Research Review*, 3(1), pp. 41-62, (2016a).
- Man, M., Ciurea, M., Elements of Corporate Governance Implementation in Romania, in the European Context, *Annals of the University of Petrosani. Economics*, vol. 16 (1), p. 151-166, (2016b).
- Munteanu, V., Tilea, M.D., Bleotu, V., Zaharia, D. L., *Contabilitate şi raportare financiară în instituţiile publice. Ediţia a II-a revizuită*, Editura Universitară, Bucureşti, (2014).
- Nicula, V.C., Bragadireanu, C., Standardele Internaţionale de Contabilitate pentru Sectorul Public (IPSAS) în Romania, *Romanian Court of Accounts Journal*, No. 9, pp.11-18, (2017).
- Nistor, S. C., European Union under the pressure of creating a competitive public accounting system, *International Journal of Competitiveness*, 1 (2), pp.136-154, (2017).
- Pitulice, C., Adoptarea contabilităţii de angajamente în sectorul public din România, *Revista Română de Statistică* nr.1, pp.55-65, (2013).

- Ristea, M., Jianu, I., Jianu, I., Experiența României în Aplicarea Standardelor Internaționale de Raportare Financiară și a Standardelor Internaționale pentru Sectorul Public, *Revista Transilvană de Științe Administrative*, nr.1(25), pp. 169-192, (2010).
- Tudor, A.T., Crișan, A., Elemente IPSAS regăsite în reglementările românești de contabilitate pentru sectorul public – Armonizarea formală (I) și (II), *Expertiza și auditul afacerilor*, nr. 36, 37, (2017).
- Tudor, A.T., Romanian Public Institutions Financial Statements on the Way of Harmonization with IPSAS, *Accounting and Management Information Systems*, vol. 9(3), pp. 422-447, (2010).
- Rakos, I. S., Man, M., Cost Budgeting - A Relevant Instrument for Improving the Performances of a Coal Mine Case Study: Jiului Valley, Romania, *Journal of Accounting and Auditing*, Vol. 2016, pp.1-22, (2016).
- Consiliul pentru Standarde Internaționale de Contabilitate pentru Sectorul Public, Manualul de Norme Internaționale de Contabilitate pentru Sectorul Public, Vol. 1 și 2, traducere, Editura CECCAR, București, (2016).
- Ordinul Ministrului Finanțelor Publice nr. 2021/2013 pentru modificarea și completarea Normelor metodologice privind organizarea și conducerea contabilității instituțiilor publice, Planul de conturi pentru instituțiile publice și instrucțiunile de aplicare a acestuia, aprobate prin Ordinul ministrului finanțelor publice nr. 1.917/2005, publicat în Monitorul Oficial nr.831/24.12.2013
- <https://www.ipsas.eu/en/ipsas-the-standards> (Accessed on 2.09.2018).
- [www.ifac.org](http://www.ifac.org) (Accessed on 10.08.2018).

## The planning of business processes in undefined condition of oligopolistic market

Alexakhin A.V.<sup>a</sup>, Zaytsev I.M.<sup>a \*</sup>, Sala D.P.<sup>b</sup>

<sup>a</sup> NUST MISIS, Russia, Moscow

<sup>b</sup> AGH, Poland, Krakow

---

### Abstract

**Methodology** – we have carried out a review of the current state of the market secondary metallurgy of precious metals. The basic tenets of the theory of antagonistic games and show their application in an oligopolistic market recyclers of electronic scrap. It is shown that decision-making in the field of business process is advantageously carried out on the basis of market monitoring and behavior of other contracting parties, in particular, to their pricing decisions.

**Originality/value** – The models, which can formalize the behavior of companies in an oligopolistic market and find a solution under conditions of uncertainty. The proposed rules non-cooperative interaction and competition rules are making management decisions on planning business processes, in particular, to ensure the natural resources of the enterprise.

**Findings** – Improving the competitive strategy of raw materials procurement is possible through the use of guidelines defining their behavior in a competitive environment that include elements of game theory. Non-cooperative game models of interaction and competition can be used in the planning of business processes. Application management advice supply of raw materials necessary to make now can be used to implement the ability to manage the volumes supplied raw materials to attract more number of suppliers in the development of business processes, in particular in the field of planning, supply of raw materials on the basis of long-term relationships.

**Keywords:** macroeconomics; game theory; oligopolistic market; decision making under uncertainty; management

---

### 1. Main text

Many authors in their articles describe undefined conditions in some business [1,2,3,4,5,6,7] and in different regions [8,9,10,11,12,13,14]. To ensure a stable position in the market, the enterprise needs to improve approaches related to strategic management, in particular, to develop a competitive strategy for providing resources using specially created economic mechanisms. One of the areas for improving the strategy can be the application of a scientifically based management system to ensure the process of rational procurement of raw materials, which will enable detailed planning of the business processes of the enterprise. Managing the process of rational procurement of raw materials of the necessary composition is expedient to implement, using elements of game theory.

The game is a mathematical model of the conflict situation. The model of the behaviour of persons in the form of a game can be used when several firms try to win the most advantageous place in a competitive market, or, for example, if several people (companies) wish to divide a certain amount of the product (resource, funds) among themselves so that everyone gets It is possible more. The theory of games is the mathematical theory of decision-making in conflict situations [15]. Players in conflict economic situations modelled as a game can be industrial and non-productive firms, banks, individuals and other economic agents. For games, the outcome (outcome) is uncertain. Uncertainty is of strategic origin: the player does not know what kind or mode of action his opponent holds, that is, the uncertainty comes from another person. The corresponding games are called strategic games.

In Russia there are more than 100 enterprises that have registration certificates of the State Assay Chamber of the Russian Federation for the right to collect and process secondary raw materials containing precious metals. The largest of them, capable of processing large amounts of raw materials, include the following: OAO Kirovograd Copper Smelting Plant; JSC "Prioksky plant of non-ferrous metals"; JSC "Krasnoyarsk Plant of Nonferrous Metals named after

---

\* Corresponding author. .

E-mail address: ivan\_zaytsev@hotmail.com

VN Gulidov"; JSC "Shchelkovo Plant of Secondary Precious Metals»; ООО Mosexpo-metal. Consider the application of the theory of games in a conflict situation, when several enterprises of the secondary metallurgy of precious metals are interested in purchasing a batch of raw materials, that is, electronic scrap, that has arrived on the market. At present, throughout the world, including in Russia, the volume of electronic scrap, suitable for secondary processing for the purpose of extracting precious and non-ferrous metals, is growing at a fast pace. This is due to the technical re-equipment of industries, the modernization of the fleet of computers and other electronic devices at enterprises, organizations and military units. The extraction of precious metals from recycled materials is part of the problem of using returnable resources. The formed wastes, on the one hand, cause great damage to the environment, on the other hand they represent the most valuable resources, in terms of the content of useful components hundreds and thousands of times superior to natural sources. The rise in gold prices observed in recent years and the consistently high prices of other precious metals such as silver, platinum, palladium make it economically advantageous to process electronic scrap.

The competitive environment is fairly homogeneous. The aforementioned plants have the technical capabilities to process a wide range of raw materials, except for computer equipment of domestic and foreign production (personal computers, workstations, servers, general-purpose computers, peripheral facilities), electronic, radio electronic and electrical equipment, Ashes of porcelain manufactures, sludge of gold electrolysis. The range of services and price lists for all plants are approximately the same. Since enterprises capable of processing large quantities of any raw materials in the secondary processing of precious metals are few, and each of them, having a certain influence, is forced to reckon with the presence and behavior of other counterparties, the secondary metallurgy market belongs to the oligopoly. The behavior of firms in the oligopolistic secondary metals market of precious metals is strategic, as each of them is compelled to take into account the possible retaliatory actions of competitors. The strategic interaction of firms under oligopoly conditions takes place in two main forms: in the form of non-cooperative interaction (when firms compete with each other and conduct more independent policy on the market) and in the form of cooperative behavior (when firms agree on joint actions and can act on the market "United front"). In the market for the purchase of electronic scrap as raw materials for processing, the interaction of enterprises occurs as a non-cooperative interaction: if a large batch of electronic wastes enter the market, then each firm is interested in obtaining it, and if one plant buys a particular lot, the other is deprived of this opportunity. Justification of recommendations for carrying out its policy on attracting suppliers is proposed to be obtained with the help of mathematical theory of games. The ability of an enterprise to determine its strategy can be achieved through the use of models of non-cooperative behavior, namely, models of antagonistic games. The antagonism of interests creates conflict, while the coincidence of interests reduces the game to pure coordination, accordingly, such situations can be reflected by non-cooperative or cooperative games. In a conflict situation, decisions are made not by one individual but by several participants, and the winning function of each depends not only on its strategy, but also on the decisions of other participants. If the players are two, and their interests are opposite, then the game is called antagonistic. The basic concepts of the theory of antagonistic games were introduced by E. Borel [16, 17].

We consider a model of a finite (in terms of the number of players and their strategies) games with complete information, in which two parties with opposite interests participate. This game is usually called the ultimate game of two persons with zero sum or antagonistic. At the disposal of each player there are many strategies. The antagonistic game is given by the aggregate  $\Gamma = (X, Y, F(x,y))$ , where  $X = \{x_1, x_2, \dots\}$  – set of strategies for the first player,  $Y = \{y_1, y_2, \dots\}$  – Set of strategies for the second player. A strategy is understood as a set of rules (principles) that determine the choice of an option for each personal move of the player, depending on the situation. Player 1 chooses strategy  $x$  from  $X$ , player 2 chooses strategy  $y$  from  $Y$ . The normal form of the game implies that each player chooses his strategy independently, not knowing the choice of partner.  $F(x,y)$  – The payoff function of the first player, defined on  $X \times Y$ . In a zero-sum game, the first player's  $F(x, y)$  win is the loss for the second player. The second player's win is therefore  $-F(x, y)$ . The first player's goal is to increase his winnings  $F(x, y)$ , and the second goal is to decrease  $F(x, y)$ .

The strategic behavior of firms buying electronic scrap can be considered as a model of game dynamics, when the game is repeated at certain points in time and the state of the economic environment is changing. Models of this type are constructed as an alternative to static optimality principles, such as the Nash equilibrium and dominance solution. Consider the situation on the interaction of competing enterprises in the market for the purchase of electronic scrap, when a large consignment of raw materials enters the market. This situation can be considered as a conflict, since there are several participants in this market, each of which pursues opposite goals, and the result of the event on each side depends on the actions of the competitor. It is assumed that the operation (game) is conducted against a reasonable opponent (competitor), pursuing its own goals and consciously opposing the achievement of the goal by the other participant. So, if a large consignment of raw materials comes to the market after the technical re-equipment of some large organization, then each potential processor tries to acquire it, thereby counteracting the acquisition of this party by another participant. The result of the game is victory or defeat, which in some cases can be conditionally expressed in numbers, for example: 0,  $\frac{1}{2}$ , 1. The conflict situation in such a market is determined by the following features: the presence of 2 or more parties to the conflict, in this case, the enterprises-processors of electronic scrap; each participant has a set of strategies  $X=\{x_j\}$ ,  $j=1\dots m$ ; increase or not increase the price of a certain kind of raw materials in relation to equilibrium prices. each participant has information about the set of strategies of others, but does not know which strategy will be adopted by either of them; the effectiveness of the actions of any participant is determined using the

efficiency function  $E$ ; the effectiveness of each participant's actions depends not only on his own, but also on the strategies chosen by other participants. All these features are inherent in the oligopolistic market of this industry. It is believed that oligopolistic relations are antagonistic. If the effectiveness of each activity is evaluated as a function of  $E_1$  and  $E_2$ , then  $E_1 = f(X, Y)$ ,  $E_2 = f(X, Y)$ , where  $X$  and  $Y$  are sets of strategies of conflicting players, then condition  $E_1 = -E_2 = E$ . If one of the oligopolists buys a batch of raw materials, the other loses this opportunity, so this conflict situation can be described as a zero-sum game model, when one of the players wins as much as the other [18].

The development of the game in time is represented as a series of successive "moves". The moves can be conscious and random. A conscious move is a player's choice of one of the possible options for an action (strategy) and making a decision about its implementation. An antagonistic game is called a matrix game if the sets of player strategies are finite:  $X = \{x_1, x_2, \dots, x_m\}$ ,  $Y = \{y_1, y_2, \dots, y_n\}$ . The possible variants (outcomes) of the game are reduced to a rectangular table - a payment matrix in which the lines correspond to the different strategies of the first player, the columns to the strategies of the second player, the values in the cells are called the price of the game. Element of the matrix  $u_{ij}$  - player 1 win if he applies the strategy  $x_i$ , and his opponent is a strategy  $y_j$ . In the game of two persons with zero sum, as in any other strategic game, the outcome depends on the behavior of both players. The goal of the theory of games is to develop recommendations for the different behavior of players in a conflict situation, that is, to choose the optimal strategy for each of them. To find the optimal strategy, it is necessary to analyze all possible strategies and to expect that a reasonable opponent for each of them will respond in such a way that the other player's winnings are minimal [19]. If player 1 does not know how his opponent will act, then, acting most expediently, not wishing to take risks and believing that the enemy will also act expediently, he will choose a strategy that guarantees him the greatest of the smallest wins for any opponent strategy. The preferred, or cautious strategy for the first player is to select the maximum value from the minimum in each line:  $\alpha = \max \min u_{ij}$ , where  $\alpha$  - maximized winnings, and the corresponding strategy is maximin. If you stick to the maximin strategy, then for any behavior of the competitor the first player is guaranteed a win, in any case not less than  $\alpha$ . Therefore,  $\alpha$  is also called the lower price of the game, or abbreviated to maximin. This is the guaranteed minimum, which can be provided with the most cautious (reinsurance) strategy. In turn, player 2, acting rationally, will choose a strategy that guarantees him the smallest possible loss for any opponent's actions. It must select the minimum value from the maximum in the columns:  $\beta = \min \max u_{ij}$ ,  $\beta$  - Minimax loss, the corresponding strategy is minimax. Adhering to the minimax strategy, the second player will lose at least  $\beta$ ,  $\beta$  is called the top price of the game or the minimum. The numbers  $\alpha$  and  $\beta$  are respectively the maximum guaranteed payoff of the first player and the minimum guaranteed loss of the second player. They are connected by inequality:  $\max \min u_{ij} \leq \min \max u_{ij}$ . If the equality  $\max \min u_{ij} = \min \max u_{ij}$  if the equality =  $C$ , that is, the lower price of the game equals its upper price, then  $C$  is called the price of the game or the saddle point. If a strict inequality, then it is considered that the game has no price. Finding the solution of the game consists in choosing a pair of maximin and minimax strategies that are optimal, since any deviation from these strategies leads to a decrease in the first player's gain and an increase in the loss of the second player compared to the game price. In an antagonistic game that has a solution, the components of the saddle point are the maximin and minimax strategies of the players and, conversely, any pair of such strategies forms a saddle point [20].

For games with zero sum, a pair of optimal strategies is a saddle point. The key characteristic of zero-sum games is the existence or absence of the price of the game. If the game has a price, then the optimal strategies exist and are defined equivalent in two ways: in isolation (as cautious strategies) and simultaneously by both players (as saddle points). However, there are two zero-sum game matrices for which  $\alpha \neq \beta$ , that is, the saddle point defined above is absent. The outcome of such a game is harder to define, because there is no one, the so-called pure optimal strategy for any player. In such cases it is said that there is no solution to the game in pure strategies, and they consider the so-called mixed expansion of the game, the solution of which is sought in mixed strategies. A mixed player strategy is a random variable whose values are its pure strategies. The task of the mixed strategy of the player is to indicate the probabilities (frequencies) with which his initial (mixed) strategies are selected. It is assumed that the game is repeated many times.

For a matrix game  $m \times n$  denote by  $P = (p_1, p_2, \dots, p_m)$  mixed strategy of player 1, where  $p_1 \geq 0, p_2 \geq 0, \dots, p_m \geq 0, \sum p_i = 1$ , across  $Q = (q_1, q_2, \dots, q_n)$  mixed player strategy 1,  $q_1 \geq 0, q_2 \geq 0, \dots, q_n \geq 0, \sum q_j = 1$ . Here  $p_1, p_2, \dots, p_m$  - the probability of using the player 1 in the mixed strategy of his pure strategies  $x_1, x_2, \dots, x_m$ ;  $q_1, q_2, \dots, q_n$  - the probability of using the player 2 in the mixed strategy of his pure strategies  $y_1, y_2, \dots, y_n$ . The expectation of player 1 win:  $M(P, Q) = \sum \sum x_{ij} p_i q_j$ . A mixed strategy that guarantees the player the greatest possible average win (or the smallest possible average loss) is called its optimal mixed strategy, and the strategies from which the optimal mixed strategy is formed are defined as profitable strategies. Let  $P^*$  - mixed strategy player 1,  $Q^*$  - mixed strategy player 2. The situation  $(P^*, Q^*)$ , with which  $M(P, Q^*) \leq M(P^*, Q^*) \leq M(P^*, Q)$ , the saddle point of the mixed expansion of the game, and the mathematical expectation of the gain  $v = M(P^*, Q^*)$  - at the cost of the game, always  $\alpha \leq v \leq \beta$ .

Consider a single repetition of the game, that is, the actions of competitors in the field of pricing when purchasing one indivisible batch of raw materials. Suppose that the supplier's preferences depend only on the price offered by the enterprise - scrap recycler. In this case, the game is antagonistic, because the interests of the players - scrap buyers are opposite. Each enterprise, aware of the intention of the provider to sell a certain amount of electronic scrap, is interested in the given batch of raw materials being supplied to it, rather than to another enterprise. This game makes sense in case of players' knowledge of the actions of competitors. In the event that one of the players is aware of the prices offered by the second, he can raise his price, of course, if he has the financial means to raise the price. If the 1<sup>st</sup> raised the price,

and the second one does not, then the "played out" consignment of raw materials is more likely to enter it. Otherwise, if the price is raised only by the 2nd player, the consignment of raw materials will go to it. If both buyers offer equilibrium prices, then raw materials with equal probability can get both the 1st and 2nd player. Let's designate as 0 the result of the game, when the plant 1 does not buy the given amount of raw materials, 1 - buys and  $\frac{1}{2}$  when the given batch with equal probability can arrive both at the plant 1 and at the plant 1.

In an antagonistic game, the principle of equilibrium is consistent with the principles of optimizing the players for their guaranteed results. If the players, that is, the enterprises that purchase raw materials, have chosen the components of the saddle point as a strategy, then each of them does not benefit from deviating from the chosen strategy. The saddle point is a formalization of the concept of equilibrium in the game. But if one of the players does not benefit from equilibrium, he will deviate from him. With reserves to increase purchasing prices, one of the enterprises can offer the seller a higher price than the competitor, thereby deviating from the optimal strategy and breaking the price equilibrium.

If the prices are balanced, the supplier's preferences depend on other factors, such as-the possibility of processing a large volume of electronic scrap; possibility of processing any types of electronic scrap; the magnitude of the transport tariff, the distance from the buyer to the seller; transport accessibility of the enterprise - processor, possibility to accept the cargo, arrived by the railway; the supplier's knowledge of extraction technologies used in a particular enterprise; the relations between the supplier and the processor; the speed of calculations. When considering the continuous activity of enterprises, the conflict situation is described by a game with finite sets of strategies, and the game is repeated at times  $t = 1, 2 \dots n$ . Before the sale of the next batch of raw materials, the potential supplier collects information on the prices offered for this type of raw materials, on the enterprises located in the scrap collection area, or in nearby regions ready to receive this raw material, on the possibility to take scrap at a certain time, on insurance costs and On the other criteria listed above. If it is possible to send the goods by mail with a small amount, the seller takes into account the speed of delivery. Enterprises that are informed of the arrival of the next batch of raw materials can choose their strategies from a finite set of strategies: to offer higher purchase prices compared to competitors, or to interest the seller with other conditions.

The process of finding a solution to a game can be considered as iterative, when players choose their strategies several times according to certain rules. Such a process is called the Brown's iteration process or the Brown method [2]. It consists in repeatedly playing a matrix game, in which players, according to certain rules, choose their strategies. At the first step, players randomly choose strategies, at + 1 step players choose strategies as the best response to the corresponding move of the partner. If there are several best answers, then any of them is chosen. Each player has at least one optimal strategy. The decision of the game, that is, the equilibrium situation, is when the difference between the two following values becomes less than a certain number  $\epsilon$ . In this case, the strategy of the first player will be maximized, and the second - minimax. In the Brown method, the limit points of sequences of strategy use by players are optimal mixed strategies. In addition, the limit point of the iterative process sequences is the equilibrium situation of the game. If the sets of player strategies are finite, then the mixed strategy is defined as the probability distribution, i.e. The probability of choosing one strategy as a real one. The equilibrium situations in such a game are called mixed Nash equilibria. In any game with finite sets of strategies, there is a mixed Nash equilibrium [3]. If, with a cumulative approximate equilibrium of other conditions, one of the enterprises will consistently increase purchase prices, then the other should pursue the same policy, and eventually the equilibrium will be established at a different level.

A rational approach to finding the price of a game assumes that each player forms his or her assumptions about the behavior of the rest and builds the best answer based on these assumptions. These principles of decision-making require for their implementation a full awareness of players about the conditions of the game (that is, with respect to the sets of strategies and functions for winning all participants). Players must be rational in making their own decisions and assume the same rationality from their partners. An infinite sequence of situations is called a process trajectory. Each participant chooses a pricing strategy - to raise or not raise prices - to the next step, based on the history that has developed by this period. The strategic decisions made today depend on the previous games or at least on the initial position. This behavior is called adaptive, its meaning is that the player predicts the probability of implementing partner strategies based on the background, and maximizes his own winnings based on such a forecast. In this case, the adaptive process converges to the equilibrium situation.

The considered models of single and multiple repetition of the game assumed the same level of awareness of players about the actions of competitors. In the oligopolistic market for the purchase of electronic scrap as raw materials for subsequent processing to extract gold and other valuable components, an asymmetric distribution of information naturally arises. Such a situation is described by the model "behavior like leader-led in the game of two persons." Each player, having received information about the strategy of another player, forms his best answer. The best answer for each player is to maximize your winnings. But at the same time one of the players is the market leader and has information about its winning function (the result of applying its strategy) and about the function of winning a competitor. This information he uses to predict the reaction of the second participant. The second player (slave) perceives the strategy of the first player as given exogenously and maximizes his own win, believing that the strategy of the first player is fixed. Thus, player 1, having the first move and foreseeing that player 2 uses one of the best answers to the behavior of the 1st, will find the optimal solution. This situation is called the Stackelberg equilibrium. The use of the Stackelberg balance requires cooperation from players, which is not always possible.



In this situation, one of the firms is stronger than the rest and has the opportunity to dictate its price to the market. Such a game is a struggle for leadership: if players are informed about each other's preferences, then it turns out to be beneficial to have the first move and force the other player to take the position of the slave [4]. The leader in the procurement of raw materials can be an enterprise that has significant production capacity, cost advantages, and also has a qualified PR-service to collect and process information necessary for the procurement and production.

In the Russian market, purchases of raw materials for the production of secondary precious metals have the greatest impact on the market by 5 large processing enterprises that provide services for the refining of precious metals. Each of them is characterized by significant production capacities and a constant specific cost of produced products, in particular, gold bullion. Scrap as raw material for processing is classified either by the percentage content of gold, or by its origin, depending on the sphere of production (in the jewelry industry, electronic, electrochemical, defense, radio industry, domestic waste). The percentage content of valuable components in various types of raw materials is established, and when receiving a specific batch for processing, the plant pays the supplier half of the value of gold contained in this scrap form according to passport data. For products in which there is no data on precious metals, a calculation is made taking into account the number of electronic components. For various types of raw materials, such as transistor glass insulators, printed circuit boards, IBM computers, scrap of electronic systems of airplanes and tanks, the generalized component composition of mixed scrap of electronic devices, there are equilibrium prices. But the increase in purchasing prices by one enterprise cannot but cause the reaction of other participants. If one of the enterprises has an advantage in costs, then it can become a leader in the industry and increase procurement prices, thereby violating the existing balance. Advantage in costs can be based, for example, on the use of technology for the integrated use of raw materials, that is, extracting from electronic scrap not only gold, but also other valuable components, which allows you to obtain additional profits from the sale of precious and non-ferrous metals and their products

## 2. Results

The models considered allow us to formalize the behavior of companies on the oligopolistic market and find a solution to the game in conditions of uncertainty. This will make it possible to develop recommendations for making strategic decisions from the point of view of the mathematical theory of games for providing raw materials with the necessary composition. Thus, the proposed rules of game models of non-cooperative interaction and competition are elements of the basis for planning the business processes of the enterprise and the principles of implementing a competitive procurement strategy, on the basis of which it is possible to implement long-term plans for an enterprise to improve the economic state.

## References

- Alexandra V. Gridchina , Vitaly M.Smolentsev , Andrei A.Ksenofontov , Elena V. Nekrasova ,Igor P. Skvortsov, Vera M. Mineeva Process Approach to Management – the Concept of Enhancing Efficiency of Company's Economic Activity International Journal of Applied Business and Economic Research 27, - Vol 15 • Number 13.
- Alexandra V. Gridchina , Anna Maltseva , Elvira Maimina ,Igor Veselov Identification of development models of scientific organizations for management objectives Ponte Academic Journal May 2017, Volume 73, Issue 5.
- Jarosław Rybak, Alexander Ivannikov, Elena Kulikova, Tomasz Żyrek Deep excavation in urban areas – defects of surrounding buildings at various stages of construction. MATEC Web Conf. Volume 146, 2018 9th International Scientific Conference Building Defects (Building Defects 2017), Section - Mechanical and Materials Engineering. <https://doi.org/10.1051/mateconf/201814602012>.
- Elena Kulikova, Alexander Ivannikov, Renata Galikbarova Engineering protection of the metropolis territories from geochemical risk in underground construction. Proceedings of International Conferences on Geo-spatial Technologies and Earth Resources (GTER 2017), Hanoi, Vietnam, 5-6 October, 2017. - (pp. 715-717)
- N.V.Novicova, K.A.Barmuta, V.A.Kaderova, D.P.Ilyaschenko, R.E.Abdulov, A.V.Aleksakhin Planning of New Products Technological Mastering and its Influence on Economic Indicators of Companies. International Journal of Economics and Financial Issues. ISSN: 2146-4138. Available at <http://www.econjournals.com> № 6 (S8), 2016, c. 65-70.
- Alexander Yuryevich Anisimov, Anna Sergeyevna Obukhova, Yulia Vladimirovna Aleksakhina, Anna Valeryevna Zhaglovskaya, Andrey Andreevich Kudra Strategic Approach to Forming a Human Resource Management System in the Organization. International Journal of Economic Perspectives, 2017, Volume 11, Issue 2, 442-448.
- Alexandra V. Gridchina, Anna Maltseva, Natalia Barsukova, Tatiana Kuzmina. Analytical Review of the Contemporary State of the Russian Scientific Organizations from the Development Management Position Journal of Applied Economic Sciences Volume XII Issue 5 (51) Fall 2017
- Yuliya V. Aleksakhina, Lyudmila E. Zimovich, Irina V. Khaibullina, Svetlana S. Nosova, Svetlana V. Lyubimtseva. Features of Development of Regional Economy and Macroeconomic Trends in the XXI Century. International Journal of Economics and Financial Issues, 2016, - Vol 6 • Special Issue (S1) - PP.

- Yuliya V. Aleksakhina, Svetlana V. Larina, Nadezhda V. Klimovskikh, Elena A. Gorlova, Yuri N. Shedko. Becoming and Growth of Cluster Management in the Regional Economy of Russia International Journal of Applied Business and Economic Research, 2017, - Vol 15 • Special Issue (S1) - PP.
- Alexandra V. Gridchina, Olga V. Grigorenko, Denis A. Klyuchnikov, Inna N. Litvinenko, Eugeny P. Kolpak The development of Russian-Chinese relations: Prospects for cooperation in crisis. International Journal of Economics and Financial Issues, 2016, - Vol 6 • Special Issue (S1) - PP.
- Alexandra V. Gridchina, Anna Maltseva Allocation of Management Zones of Territories of Innovative Development: Methodical Basis. Journal of Applied Economic Sciences, 2016, - Vol XI Issue 6(44).
- Alexandra V. Gridchina, Lyudmila Orekhova, Svetlana Lyubimtseva, Nataliya Yakovenko, Igor Komov. Agrarian Policy of the Region in Terms of Economic Development Innovation. International Journal of Economics and Financial Issues, 2016, - Vol 6 • Special Issue (S1) - PP.
- A.Y. Anisimov, Y.S. Polozhentseva, A.V. Zhaglovskaya, A.V. Aleksakhin. Regional monitoring of staffing support in the coal mining industry. «Eurasian mining», № 2, 2017, c. 53-56.
- Jaroslav Rybak, Alexander Ivannikov, Alexandra Egorova, Kristina Ohotnikova, Isabel Fernandes. Some remarks on experience based geotechnical education. 17th International Multidisciplinary Scientific GeoConference SGEM 2017, www.sgem.org, SGEM2017 Conference Proceedings, ISBN 978-619-7105-99-5 / ISSN 1314-2704, 29 June - 5 July, 2017, Vol. 17, Issue 12, 1003-1012 pp, DOI: 10.5593/sgem2017/12/S02.127.
- Vasin A.A., Morozov V.V. Teoriya igr i modeli matematicheskoy ekonomiki. M.: MAKSPress, 2005 g.
- Borel E. The theory of play and integral equations with skew symmetric kernels. Econometrica. 1953. V. 21. № 1. P. 97 - 117.
- Mulien E. Teoriya igr s primerami iz matematicheskoy ekonomiki. M., Mir, 1985.
- Glukhov V.V., Mednikov M.D., Korobko S.B. Matematicheskiye metody i modeli dlya menedzhmenta. SPb.: Izd. «Lan'», 2000.
- Avdasheva S.B., Rozanova N.M. Teoriya organizatsii otraslevykh rynkov. M., ICHP «Izdatel'stvo Magistr», 1998.
- Afanasyev M.YU., Suvorov B.P. Issledovaniye operatsiy v ekonomike. M.: Ekonomicheskii fakul'tet MGU, TEIS, 2003 – 312 s.

## The planning and management of the owner's earning with using simulation modeling

Alexakhin A.V.<sup>a</sup>, Rozhkov I.M.<sup>a</sup>, Zaytsev I.M.<sup>a\*</sup>, Yu. Kostyukhin<sup>a</sup>

<sup>a</sup>NUST MISIS, Russia, 119049 pr. Leninskii,

---

### Abstract

This papers aimed at the usage of automatic control systems by the financial situation of a company. The solution of this task includes three steps. The first step is the creation and the forecast of the integrated factor which define the financial condition of a company. Owner's earnings were selected as this factor. Then analyze the level of influence of the financial coefficients on the selected integrated factor. The second step is the creation of the estimated vector. The methodic of the assessment of company's financial position using the new characteristic – “the length of the integrated factor”, which defines by financial and statistical coefficients. The vector allows dividing the array of initial data into two parts related to satisfactory and pre-crisis periods of the enterprise that makes possible to build a separate forecast model for the main indicator for crisis data and for satisfactory data. Probability density functions were built for each group of data. The final step is the modeling on purpose to find the optimum value of owner's earnings of the company using a change of financial coefficients were recommended like as management decisions. Authors present the block diagram of the below steps for solving the task set: the creation of listed ratios, the calculation of the estimated vector and the determination of rational values of management decisions. Shows the results of two simulations experiments for Russian steel company – NLMK group.

*Keywords:* imitating modeling, owner's earnings, the sliding value of a vector of assessment of an economic situation; rational values of the financial ratios used as corrective actions

---

### 1. Main text

The need to develop new company management systems is conditioned by the fact that the existing methods of management of industrial enterprises on the basis of financial indicators, have a number of significant limitations:

- a) ignore or incorrectly assess the value of intangible assets of the enterprise;
- b) does not take into account the expectations of the main stakeholders of the company;
- c) late responds to changes in the external accident;
- d) do not allow to determine how this or that factor affects the results of the company due to the high aggregation of indicators used.

If we consider an integrated industrial structure as an object of management, it will be a complex system, which according to the theory of systems, has a goal and objective function, elements and links of elements of control links, the result of the system and the system effect. In Russia, for many years it was believed that the main motive of the company is to make a profit, but in the foreign literature on management and finance for several decades, the criterion of profit maximization is recommended to use only for management decisions in the short term. Profit has several significant disadvantages that can distort effective financial management decisions in the long term. It can be noted its four basic drawbacks:

- 1) first, the profit is a static indicator, that is, the time factor is not taken into account;
- 2) second, it does not take into account risk, which is a critical category in financial decision-making;
- 3) thirdly, the profit is calculated accounting in nature, not monetary, therefore, in principle, any profitable enterprise might be financially untenable, as the cash could be insufficient to meet future obligations;
- 4) fourth, the calculation of profit is ambiguous, since it has many types-for example, gross, net, retained earnings, etc.

---

\* Corresponding author. Tel.: +0-000-000-0000  
E-mail address: ivan\_zaytsev@hotmail.com

The effectiveness of the enterprise - a comprehensive multilateral concept. Depending on what theory underlies the management of the efficiency of the enterprise and different approaches to management.

Here are listed the main approaches and theories of enterprise efficiency management from the standpoint of their evolution.

1) Transaction approach. Can be considered historical one of the first methods. At the heart of this approach, the company is presented as a set of contracts. This particular type of contractual arrangement, combined with the coordinated use of resources, creates savings in transaction costs compared to the coordination provided by the market.

2) the Resource-based approach started to develop activities in the mid-1980s — early 1990s, at this time, the company is considered as a bundle of resources. The economic performance of firms operating in the same product market depends on the composition of the resources they have and use in their work.

3) The approach based on knowledge (PAHO), was also developed in the first half of the 1990s, the knowledge was regarded as the most important resource efficiency and competitive advantage of the enterprise. Now companies learn and develop the knowledge created by individuals. The company better than the markets organized a combination of knowledge, i.e. approved "atindependent" knowledge, whereas traditionally they were considered exclusively owned by individuals.

4) on the basis of the previous approach, the concept of dynamic abilities (CDU) was formed. An important branch of the knowledge-based approach (POS) is the dynamic capabilities of the firm (DS). Dynamic abilities of the company are changing internal and external organizational skills, resources and functional competencies that determine the direction of development of competencies formed under the influence of past experience. The object of analysis in the CDU are only those companies that operate in dynamic, innovative sectors.

5) the Entrepreneurial theory of the firm (PTF) focuses on the need of the business activities of firms operating in a global and dynamic competitive environment.

6) Process approach and behavioral theory of the firm. The term "process" has three different meanings in this approach: the first as the logic of causation linking independent and dependent variables; the second as the type of concepts or variables reflecting the actions of individuals or organizations; and the third as the chronology of events describing the change of things over time.

7) the Strategic theory of the firm (STF) is considered as "integrative", including all the set of theories of the firm that arose after the neoclassical - transactional, resource approach, the concept of dynamic abilities, etc. Note that if the previous theory took into account only certain parts of the company's efficiency, the strategic theory of the firm allows taking into account all the important factors. The formalization of the strategic approach is the concept of BPM - Business Performance Management (business performance management) or CPM — corporate performance management, EPM - enterprise performance management.

Since the term "efficiency" belongs to the economic category and is the "sister" of performance, the managerial category, it is important not to confuse these concepts. In a market economy, a prerequisite for effective functioning is the balance of interests of all business participants: owners, management and production workers. All members of the organization are interested in the effective work of the enterprise. The results reflect the key objectives of the organization based on the existing strategy. They are divided into economic and non-economic results. Non-economic results (for example, the result of work on environmental conservation) do not have effects in value form. If the result of economic activity exceeds the costs, then there is a positive economic effect, which for example can be considered as a profit; the otherwise-a negative effect, such as losses. The effect, as the difference between the cost of the product and the cost of its production, may appear, *ceteris paribus*, in two cases: the first-increases the product, or the growth of production; the second – when the cost of production of the product is reduced (saving resources).

There are four groups of performance indicators of the enterprise.

1. Indicators of efficiency assessment of economic (operational) activity of the enterprise. The ratio of the resulting parameters (profit, revenue) and the amount of used, applied or total resources (assets, equity, etc.) is estimated. Traditionally, it is believed that the main performance indicators are in this group, gradually this position loses its force.

2. Criteria and indicators of efficiency of investment activity of the organization. This group of indicators should primarily be linked to the interests of investors as a key stakeholder in capital investment in General and specific projects in particular. Calculation of economic efficiency of the investment project is a special category of financial and economic analysis of the company.

3. A group of performance indicators of certain types of resources used in business: labor, stock (capacity), financial. In this group, the bulk of the dual-use criteria that extend the boundaries of classical efficiency is concentrated.

4. Financial indicators of economic efficiency of production in the context of goods, works, services at the level of individual positions, production units, strategic business units.

For managers and owners of organizations has always been an urgent problem in determining the effectiveness of enterprises. All efforts were aimed at increasing revenues and reducing costs. However, the requirements for determining and improving the efficiency of the enterprise have become more stringent over time. There is a certain process of increasing the efficiency of company management. It includes the following steps:

- assessment of external factors that may affect the efficiency of enterprise management;
- identification and classification of necessary knowledge and skills;
- definition and analysis of requirements to the Manager;

- forecasting changes in management requirements in the development of the company and its environment;
- assessment of senior staff;
- approval of the most important tasks in the areas of production and management.

At the moment, you can see an increasing interest in the concept of management based on the value of the company, which has been actively developing for several decades abroad and relatively recently in Russia. In the modern concept of value-based management ("Value Based management") the basis for management decisions is the maximization of shareholder wealth, which means maximizing the net market value of the business. The model based on the Value Based Management concept allows transforming the system of drivers of the company's value growth into key performance indicators (KPI) for the company's management. Despite some differences in the construction of management decisions, all the main existing models are based on forecasting the current and expected cash flows of the enterprise, analysis of financial and operational risks, determining the cost of debt capital and growth potential for the company's business.

On the process of formation of the company's value is influenced by the factors of micro - and macro-levels. Therefore, events that occur both in the economy or in the financial sector, politics, and in the social sphere, can have an impact on the performance of the company, including – on the value of the company. In order to implement long-term plans, the company needs to correctly identify key cost factors and ensure continuous monitoring of their values. Factors or drivers of the company's value formation should show the level of efficiency not only at the current time but also show the prospects for growth in the long term. An important task is to determine the direct or indirect impact of the value creation factor, and to what extent.

Now the most important and common methods for analyzing the efficiency of the enterprise are economic value added, added value of cash flow, added shareholder value and return on investment and owner's earnings. In this papers we will look at and analyze owner's earnings. The first how started to use this indicator was an American business magnate Warren Buffet. Owner's earnings represent (A) reported earnings plus (B) depreciation, depletion, amortization, and certain other non-cash charges such as Company N's items (1) and (4) less the average annual amount of capitalized expenditures for plant and equipment, etc. that the business requires to fully maintain its long-term competitive position and its unit volume.

It is established that there is a very strong correlation between owner's earning to assets coefficient, turnover asset ratio ( $x_1$ ), current ratio ( $x_2$ ) and long term liabilities divided to assets coefficient ( $x_3$ ). Using the step-by-step regression analysis method, we received the most reliable variables of the following characteristics for forecasting indicator owner's earnings to assets ratio for Russian steel company – NLMK group:

Table 1. The results of regression analysis

	$x_1 * x_3$	$x_2$
Regression coefficient	2,3529	0,2824
Standard Error	0,2842	0,0240
t value	8,2787	11,7570
Multiple R	0,9738	-
R square	0,9484	-

In the automated systems of management of economy of the enterprise the problem of finding in dynamics of rational values of the operating influences providing maximization, for example, the owner's earnings indicator needs to be solved with application of simulation. The General scheme of implementation of this procedure is as follows. After selecting the main economic indicator, we proceed to find the vector that determines its financial and statistical coefficients, the so-called estimated vector  $y = (y_1, y_2, \dots, y_n)$ . In particular, for the relative owner's earnings components of the estimated vector selected above financial ratios  $x_1 = y_1$ ,  $x_2 = y_2$ , as well as the indicator  $x_4 = y_3$ . From statistics in these papers suggested to use sliding coefficient of variation: (Rozhkov et al, 2017).

$$y_3 = \frac{\sigma}{M_x}$$

$\sigma$  – sliding sample average square deviation of owner's earning;  
 $M_x$  – its expected value;

Next determine the length of the estimated vector  $\|\bar{y}\| = \sqrt{y_1^2 + y_2^2 + y_3^2 + y_4^2}$ . The coordinates of the vector are ones and zeros, that is  $y_i \in \{1; 0\}$ . The number 1 is satisfactory situation of the company and the number 0 is unsatisfactory. Values of  $y_i$  determined from the following system of relations is determined by standard values established by the company management (Larionova et al, 2001).

## **Conclusions**

An evaluation methodology was proposed economic situation of the company with application of the new characteristic is the length of the estimated vector. The methodology includes the following main stages:

- determination of a set of financial ratios and their standards characterizing the economic situation of the company;
- determine of the coordinates of the estimated vector, in which the corresponding financial ratio is replaced by 1 if it meets the satisfactory situation of the company and 0 otherwise;
- the calculation of the length of the vector;
- the separation of data into two parts: satisfactory and unsatisfactory state of the company.

## **References**

- Larionova I.A., Rozhkov I.M., Eliseeva E.N. Development of new methodical techniques for operational technical and economic planning and management of the activities of a metallurgical enterprise. *Izvestiya Visshikh Uchebnykh Zavedenii. Chernaya Metallurgiya = Izvestiya. Ferrous Metallurgy*, No. 8 (1220), Pp. 58–63, (In Russ.), (2001).
- Rozhkov I., Trofimova N., Larionova I., Kostyukhin Y. Management of the value added made by the entity using simulation modeling. *International scientific conference Industry 4.0. Borovets: Scientific Technical Union of Mechanical Engineering*, Pp. 236–237, (2017).

## The Substantiation of Cash Flows within a Business Plan

Ilie Răscolean<sup>a\*</sup>, Ileana – Sorina Rakos<sup>a</sup>

<sup>a</sup>University of Petroșani, Street Universității, no.20, Petroșani, România

---

### Abstract

This paper highlights some aspects regarding the substantiation of the cash flows within an economic entity. The main objective is to highlight the cash inflows and outflows and the cash flow during the investment project, as well as in the next period, when the company should carry out cost-effective activities to ensure reimbursement of the financing and obtain the necessary profit and the remuneration of shareholders or associates. Based on the literature, the authors present the structure of the business plan that should include: medium and long-term vision and objectives; business description and implementation strategy; SWOT analysis, human resources policy; description of the investment project, market analysis; financial projections and justification of the need to fund the project. The business plan is a predominant tool for managers - identifying funding sources, getting funding, or making partnerships with other companies. The business plan establishes the vision, objectives, implementation strategy and actions of the economic entities necessary to carry out profitable activities in the future. The authors try to contribute to the conceptual and empirical national and global framework on the substantiation of cash flows in a business.

*Keywords:* market analysis, cash flows; financing; business plan; financial projections

---

### 1. Introduction

In order to understand the concept of a business plan, we consider it useful to define the concept of a business, namely: an intention of a person (physical or legal) to undertake certain activities in order to obtain a profit. The theoretical and pragmatic approaches to the business plan differ from specialists to professionals, as evidenced by the existence, after the 1990s, of extensive literature in the field, as well as numerous issues published in various volumes, but also disseminated through the online environment, including guides to develop business plans in various business areas.

From the prestigious Harvard University, David Gumpert, (1990) realizes a realistic approach to the business plan that it is “a document that proves in a convincing manner that the business envisaged can sell enough products and services to produce a satisfactory profit and make it attractive to potential investors.”

The role of the Business Plan is to demonstrate that the business deserves to be funded and to guide the entrepreneur from the first year of operating the business, being in fact both an internal tool through which the manager manages and controls the entire process of starting an economic entity, as well as an external instrument that facilitates communication with the economic environment. The Business Plan establishes: vision, mission, goals, strategy and action plans for carrying out a specific activity during a determined future period, history, management, human, financial, and material resources, current activity, market analysis, cost analysis operation, necessary investments, financial projections and appendices thereto, including: cash-flow forecasts; any other relevant financial information; detailed description of the product or service; plans and sketches for the technological process; a detailed list of equipment owned or to be purchased; description of the investment; Cvs of management; organization chart of the economic entity; brochures and advertising materials; copies of various contracts; support letters from future customers / pre-orders; suppliers' offers; results of marketing researches; operational plans; any other material that can provide relevant information to those who will read the business plan; a list of all the assets held, adjusting this list according to the economic entity profile and the size of the investment.

---

\* Corresponding author Tel: 0722782323  
E-mail address: IlieRascolean@upet.ro



Thus, the Business Plan “transmits” to all those around the entrepreneur - customers, suppliers, strategic partners, financiers, shareholders, that the manager knows for sure what to do, and in a functioning market economy, serious business partners appreciate this and they will perceive the entrepreneur as a pertinent actor of the economic environment.

Schematically, all these aspects are shown in Figure 1.

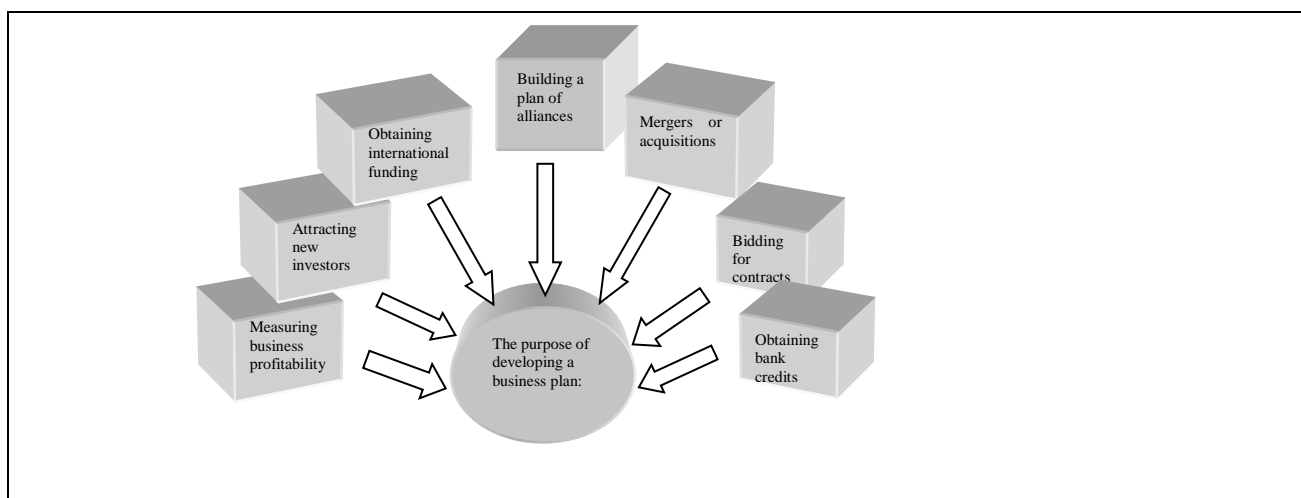


Figure no.1. The purpose of developing a Business Plan

Source: own projection

In addition to the business plan, a set of financial statements detailing cash flow is essential. This will give details about the actual amounts of money requested by an economic entity, each day, from one month to another, and from one year to the next. The needs of a business are constantly changing, and the cash flow will highlight potential shortfalls in cash that will have to be moved. Good cash flow management is essential to a successful business. It is necessary to carefully analyze the products / services offered, the competition, the necessary financial resources and other operational details. Also, the business plan is a working tool that is used to start and run a business that requires material, financial, and human resources. Through it, the experience and achievements of the past are used to design the future through the most appropriate methods of estimation and approximation. Implementing a Business Plan means control and adaptation - depending on real evolution. This control over the business will address all critical elements of the economic entity (inventories, production costs, quality control, sales, payments made, etc.). A realistic business plan always has two parts: a written part that analyzes the context (market, competition, trends) and a part that evaluates the operational and financial implications by preparing a future financial scenario (in an excel table). The Cash Flow is used to get the best value for money.

## 2. What is the cash flow?

The International Accounting Standard (IAS) 7 defines cash flows (also referred to as cash flows or cash-flow in some studies) as cash inflows or outflows and cash equivalents.

In business planning, the availability of money at the right time is a criterion that must first be taken into account when performing basic activities. The cash-flow of a business is one of the most important tools used by both managers and entrepreneurs, as well as by investors, in substantiating business decisions. Cash flow analysis is required in all economic forecasts, both for obtaining a bank credit and for financing a project through European or national non-reimbursable funds. The information provided by this cash flow analysis also serves specialists outside of the economic entity, such as:

- creditors - provide working capital and capital for investment, so they will be interested in recovering the borrowed funds;
- financiers - analyze the sustainability of the investment project over a certain time horizon, medium or long, being interested in how the company can sustain its activity without exhausting its financial resources;
- business consultants - will look at the evolution of the economic entity over a time horizon, medium or long term, being interested in all information regarding clear or estimated receivables and payments;
- investors - make the decision to attract participants into a new business, analyzing its ability to generate profit in the medium or long term.

In practice, the calculations are summed up on sources of income and costs, so if the revenue is higher than costs and profit is obtained then the investment seems appropriate. Practically, the cash flow is the clearest picture of the health of a business, showing both the earnings and payments a company has in a period of time. The longer the time horizon, the accuracy of the information will be lower, taking into account various hypotheses whose accuracy will be lower.

The most accurate information can be obtained over a time horizon of up to one year. When the analyzed time period exceeds 12 months, the accuracy of the information decreases, which makes this financial analysis tool not be sufficiently precise and real. Of the changes that may occur during a year, we can mention: the change in the VAT rate, the gross minimum wage in the economy, the tax rates and local taxes, the turnover tax rates or the income of the microenterprises, and the legislative changes this year are evidence conclusive in this respect.

### 3. Making a cash flow analysis

The main source for the analysis is the “Treasury Cash Flow Statement” prepared in accordance with the provisions of IAS 7, *mandatory* for large enterprises and *optional* in the case of small and medium-sized enterprises. The financial statement users include prospective and potential investors, hired staff, lenders, suppliers and other commercial creditors, customers, government and its institutions as well as the public. Regarding the “cash flow statement”, IAS 7 considers that it provides useful information for assessing the entity’s ability to generate cash, as well as its needs to use cash flows, respectively the timing and the safety of their generation.

The overall framework for preparing and presenting the financial statements of which the “*treasury cash flow statement*” also states that their objective “is to provide information on the financial position, performance and changes in the financial position of the enterprise that are useful to a wide range of users in making economic decisions”.

In Romania, the *treasury cash flow statement* is considered a component of the annual financial statements in accordance with the International Accounting Standards. Under the treasury cash flow scenario, according to the functional approach of the activities of an economic entity, the cash flow has three closely interconnected, so the result of one influences the others and, ultimately, the end result of the whole activity:

- the investment activity concerns the intention of the company to make new investments, acquiring goods and equipment, constructing, paying for software solutions etc .;
- the financial activity refers to the procurement of the money resources necessary for the realization of the investments: loans from associates, bank credits, own sources or non-reimbursable funds;
- the (operational) exploitation activity carried out by the company in parallel with the realization of the investment.

The duration of the economic forecast differs according to the destination that the cash-flow will have, the duration of the analysis may be limited by the repayment period of the credit, in the case of financing from national or European funds it is five years, and for internal use it is designed for one year, which ensures high precision. The cash flow is compiled for three distinct components: the investment activity, financial activity and operational activity.

The cash flow for the investment activity includes the following information: what are the necessary investments and what is their value? At what times will payments be made to suppliers? Will the investment be made within one month or is a breakdown needed over a longer period?

The cash flow for the financial activity refers to securing the financing sources from which the economic entity will support the investment. These sources can be: own financial resources when the entity is available from the prior period; loans or bank lines when the entity will lend the financial resources necessary to make an investment or to cover operational expenses; contribution of the associates or loans granted by them to the entity; European or national non-reimbursable funds when the company accesses such funding.

Often, the economic entities use a mix of four funding solutions. These cash inflows will also generate cash outflows: interest payments on contracted loans; repayments of contract credits; repayments of loans from shareholders.

The cash flow for operating activity is for the upcoming period, and it does not generate earnings or payments until the activity starts. If the activity is started, the cash flow will comprise two components, adding activities and the activity that is financed by the implementation of the investment project. This will generate a substantial increase in the company’s workload when the investment is made to expand the range of products, services. Operating revenue is: provision of services to the entity’s customers; the sale of goods and products; carrying out works. VAT must be calculated if the entity is VAT-paying.

Payments generated by exploitation are: for suppliers, for raw materials and material; for utilities; for the rent of the production hall or the office; for salaries and social contributions; taxes and duties owed to the budget; advertising and publicity.

The analysis of the cash flows on all three types of activities is useful for: correlating the profit (loss) with cash; the separation of cash-based activities from those that do not involve cash; assessing the ability of the entity to meet its cash payment obligations; cash flow assessment for future cash-flow activities. The usefulness of the analysis is given by the fact that the global variation of the treasury is evidenced by the treasury balance resulting from the real assets management (from operating activity) and from the capital-related investments and financing operations. When real and monetary flows do not coincide, as it actually happens, the treasury is provided by pay mismatches associated with these flows.

Each of the three categories of flows has an impact on a source or use of liquidity. While respecting the American accounting tradition, operating cash flows can be determined either directly or indirectly, and cash flows from investing and financing activities by direct method. According to the direct method, gross cash receipts and payments are used, and the peculiarity of the indirect method is that the net profit (or net loss) is adjusted with the effects of non-monetary transactions, deferrals or payment commitments or receipts in cash from past or future operations and the items of income and expense associated with cash flows from investment or financing activities.

Although they lead to the same results, IAS 7 recommends entities to present cash flows through the straight line method because it provides useful information in estimating future cash flows that the indirect method can not provide.

Therefore, the cash-flow can be positive or negative, which is explained as follows: if the money entering an economic entity is more numerous than the ones going out, then we are talking about a positive cash-flow. Positive cash flow is a very good thing for the entity and the only problem is managing this surplus. In the reverse situation, that is, when the money coming out of the entity is more than the one entering the negative cash-flow. The negative cash-flow can be caused - for example - by the timely non-collection of money from customers, in which case quick solutions must be found to avoid the company's inability to pay.

Also, making a cash flow analysis of an economic entity's business requires a thorough knowledge of the business and the collection of all necessary information on the proceeds and payments to be made in the future. The information to be collected is related to: the number of staff employed and estimated to be employed and the expenses of the entity are salaries and social contributions for both existing and those who will be hired during the analysis period; the structure and value of other business expenses (rents, utilities, raw materials, third parties etc.); realization of planned investments for the next period; the maximum production capacity of the entity and the degree of effective use of the entity; contracting of credits and conditions under which they will be repaid (interest rate, grace period, duration of credit etc.); - forming the sale price, the granting of volume or pre-maturity discounts etc.

For the collection of these data, a questionnaire will be made which will be sent to all persons able to provide the requested information, stating that the information can be extracted from the following documents: financial statements for the previous or previous months; staffing needs; revenue and expenditure budget for the following period; the investment plan; financial offers of equipment to determine the value of the investment; technical offers of equipment to determine future production capacity, energy consumption, fuel, etc. what these are supposed to do etc.

When calculating the cash flow, the amortization expense is not taken into account. This is not an expense involving liquidity outflows within the entity, being a way in which the entity may constitute the financial resources necessary for the future replacement of fixed assets at the end of the normal period of operation. In a cash-flow analysis, it is very important when the company collects receipts and when the company makes payments. For example, if an economic entity purchases raw materials with a negotiated three-month payment, cash outflows will not be evidenced at the time of signing the contract or at the time of delivery, but at the time of actual payment. This reasoning also applies to cash inflows from the sale of goods, provision of services, etc. A negative disposition at the end of a period (day, week, month, quarter, semester, year etc.) means that the economic entity does not have sufficient financial resources to cover current payments at that time. In this case, working hypotheses need to be redefined, taking into account the delay in paying suppliers or quickly collecting invoices issued to customers, while offering some trade discounts.

#### **4. Case Study**

A Limited Liability Company (LLC) is set up, with a share capital of 200 lei, with a single associate, also having the capacity of administrator. For the forecast period, the company falls into the category of micro-enterprises with incomes less than 1000000 euro equivalent in lei during a financial year. In order to start and carry out specific productive activities, the following sources of funding are sought:

- non-reimbursable funds partially covering the initial investment amounting to 150000 lei;
- a 5-year bank loan in the amount of 30000 lei with an annual interest rate of 10%;
- in addition, the single associate lends to the commercial company the sum of 20000 lei, and the loan is to be repaid from the liquidities generated by the profitable activity carried out after the commissioning of the investment project.

The initial value of the investment project is 200,000 lei, including the following: production hall, equipment necessary for the technological flow, provision of the necessary utilities, means of transport, offices for the administrative headquarters.

Funding sources provide funding for the investment project and cover current expenses for three months from the start of the business and partly for the next three months. Starting with the seventh month, the expenses will be fully covered by the proceeds from the sale of the production.

The cash flow for the first seven months of starting business and forecasts for the next two years are shown in the table no.1 below.

Tabel no.1. Cash Flow

Crt. No.	Explanations / month	PERIOD OF IMPLEMENTATION						PERIOD OF PROGNOSIS		
		L7	L8	L9	L10	L11	L12	2018	2019	2020
I	Initially available balance (home and bank)	200,00	198.300,00	31.342,00	16.042,00	3.645,00	4.713,00	200,00	4.980,50	4.644,50
	Cash inflows through:	200.000,00	0,00	0,00	0,00	0,00	0,00	200.000,00	0,00	0,00
	Loans from associates / shareholders	20.000,00	0,00	0,00	0,00	0,00	0,00	20.000,00	0,00	0,00
	Long-term credits	30.000,00	0,00	0,00	0,00	0,00	0,00	30.000,00	0,00	0,00
	Non-reimbursable financial assistance	150.000,00	0,00	0,00	0,00	0,00	0,00	150.000,00	0,00	0,00
	Investment liquidity outflows:	0,00	200.000,00	0,00	0,00	0,00	0,00	200.000,00	0,00	0,00
	Purchase of tangible assets, including VAT	0,00	190.000,00	0,00	0,00	0,00	0,00	190.000,00	0,00	0,00
	Acquisition of intangible assets, including VAT	0,00	10.000,00	0,00	0,00	0,00	0,00	10.000,00	0,00	0,00
	Outflows of financing liquidity:	0,00	3.500,00	3.450,00	3.400,00	3.350,00	3.300,00	17.000,00	35.700,00	28.500,00
	Credit reimbursements	0,00	500,00	500,00	500,00	500,00	500,00	2.500,00	6.000,00	6.000,00
II	Interest payments	0,00	3.000,00	2.950,00	2.900,00	2.850,00	2.800,00	14.500,00	29.700,00	22.500,00
III	Cash inflows through:	0,00	0,00	0,00	10.000,00	25.500,00	27.000,00	62.500,00	315.000,00	410.000,00
	Sales of goods and services, including VAT	0,00	0,00	0,00	10.000,00	25.500,00	27.000,00	62.500,00	315.000,00	410.000,00
	Outflows of liquidity through:	1.900,00	1.800,00	11.850,00	17.400,00	17.700,00	20.250,00	70.900,00	225.618,00	283.000,00
	Expenditure on raw materials and consumables	0,00	0,00	0,00	5.000,00	5.500,00	8.000,00	18.500,00	34.500,00	65.000,00
	Staff expenditure	0,00	0,00	10.000,00	10.000,00	10.000,00	10.000,00	40.000,00	140.000,00	190.000,00
	Rent	1.500,00	1.500,00	1.500,00	1.500,00	1.500,00	1.500,00	9.000,00	18.000,00	20.000,00
	Utilities	100,00	100,00	100,00	500,00	500,00	500,00	1.800,00	6.000,00	6.000,00
	Other expenses	300,00	200,00	250,00	400,00	200,00	250,00	1.600,00	1.800,00	2.000,00
	VAT payments	0,00	0,00	0,00	1.597,00	3.382,00	3.182,50	8.161,50	48.393,00	60.230,00
	VAT rebates		38.342,00	0,00	0,00	0,00	0,00	38.342,00	0,00	0,00
IV	Profit / turnover tax	0,00	0,00	0,00	0,00	0,00	0,00	625,00	3.150,00	
V	Dividends	0,00	0,00	0,00	0,00	0,00	0,00	0,00	5.000,00	15.000,00
	Total payments exclusive to exploitation	0,00	38.342,00	0,00	1.597,00	3.382,00	3.182,50	30.180,50	54.018,00	78.380,00
	Cash flow from operating activities	1.900,00	36.542,00	11.850,00	8.997,00	4.418,00	3.567,50	21.780,50	35.364,00	48.620,00
	Net cash flow of the period	198.100,00	166.958,00	15.300,00	12.397,00	1.068,00	267,50	4.780,50	336,00	20.120,00
	Final balance available at the end of the period	198.300,00	31.342,00	16.042,00	3.645,00	4.713,00	4.980,50	4.980,50	4.644,50	24.764,50

## 5. Conclusions

The cash flow forecasts are an important tool for leading an economic entity that can help in general business planning. In addition, the effort made to realize the forecasts will be useful as a good starting point for possible detailed discussions with the credit officer in the case of bank loan withdrawals. Without the cash there is a safe way of ending the activity of the economic entity and respectively towards insolvency, which is why it is necessary to give due importance to flows that represent cash inflows or outflows. The cash flow shows the cash movements of an entity over a certain period of time, this being the spring that makes the business go. A number of companies go bankrupt because they are not concerned about cash flow management so they can secure enough cash to honour their due obligations. Cash flow management means the tracking and forecasting of cash inflows and outflows so as to ensure the exact amount of cash needed to deal with outstanding payments at the time the payments become due.

It is important for entrepreneurs and managers to understand that focusing solely on sales volume DOES NOT ensure the sustainable success of the economic entity, which must be operationally effective and manage its financial flows with fairness. The forecasted cash flow involves estimating all the sources and future cash uses of an economic entity, depending on the strategy the entrepreneur proposes, namely: the target of increasing the volume of sales, the concluded business contracts and the payment terms, the policy the human resources, the location in which they operate, the financial resources they have or intend to attract, the seasonality of the business, the taxation, etc. It can be run monthly, quarterly, semi-annually or annually, and takes into account the trend in the past, the expected changes in the operational cycle, investment policy, financing contract features, seasonality, and last but not least, environmental changes business, politics or taxation. The fact that an economic entity is profitable is not a sufficient condition for the firm to remain solvent. A bad debt collection policy or an inappropriate managerial decision about continued output on the stock - may generate a profit accounting position, but lacking the cash needed to resume the production cycle and invest. When an economic entity does not have sufficient cash to honour its maturity, it becomes insolvent. The case study presents the cash flow for a newly established trading company that has three categories of funding sources: non-reimbursable funds, bank loans, and the single associate's contribution. The mentioned sources of funding ensure the realization of the investment project necessary for carrying out productive activities and covering some operating expenses in the first months of the activity. There is a positive cash flow generated by the profitable activity that makes it possible to make payments related to the exploitation cycle from the collection of the income from the sale of the production.

## References

- D. Gumpert, *How to Create a Succesful Business Plan*, Goldish Group, Boston, pg.6, 1990;  
Cristian Zgreabă, *Comunicarea financiară pe baza fluxurilor de trezorerie*, <http://www.oeconomica.uab.ro/upload/lucrari/820061/47.pdf>, pg. 3;  
Gearba, R., Slave, C., Covlea, M., - *Consilier Management financiar*, Editura Rentrop si Straton, pp. 73 – 200, 2010;  
Răscolean Ilie, Rakos Ileana-Sorina, *The Calculation of Economic and Financial indicators, on the basis of the Balance Sheet to the Economic Entities in Romania*, International Journal of Academic Research in Accounting, Finance and Management Sciences, Vol.7, N.4, Octomber 2017, pp.242-247, E-ISSN: 2225-8329, P-ISSN:2308-0337© 2017 HRMARS, BDI: EBSCO Host, Index Copernicus, Ulrich Global Directory, Google Scholar, <http://hrmars.com/index.php/journals/detail/9>.

## Essence and role of co-operation in regional development. RIS3 case study

Marzena Szewczuk-Stępień, Brygida Klemens\*

*Opole University of Technology, Economics and Management, ul. Luboszycka 7, Opole 45-036, Poland*

---

### Abstract

The paper presents the role and importance of co-operation in regional development. It includes the discussion on the essence of co-operation in modern economy and specification of its scope, forms and types. The deliberations on the role of co-operation are based on an analysis of regional innovation strategies which constitute one of the more important instruments for building innovation and improving the competitiveness of a voivodeship. The purpose of this elaboration was the determination of key definitions identified with the term of co-operation in Regional Innovation Strategies (the so-called RIS3) applicable in Poland until 2020. The study applied the exploratory data analysis, especially the *text mining* technique.

*Keywords:* co-operation, partnership, cluster, network, Regional Innovation Strategy

---

### 1. Introduction

A dynamic economic, political or social situation brings forth challenges for entrepreneurs and public authorities. Functioning in conditions of changes presents a series challenges for enterprises related to the need to quickly adapt production to market needs, whereas for public authorities this means, e.g. the need to propose other forms and rate of planning of pro-entrepreneurial activities. Entrepreneurs are increasingly seeking for opportunities to minimise the negative effects of their functioning in conditions of change. One of such opportunities can be co-operation and affiliation to various types of networks or organisations (Klemens, 2017). It is not a new statement that co-operation (regardless of the type of partners) brings substantial benefits for all parties involved. These can include financial, political, social and personal benefits. These types of benefits can also be defined in terms of regional development.

Taking into consideration the regional innovation policy in Poland, it is necessary to note that it is a relatively new area of activity of local government authorities, because regional innovation systems were started to be built only after regional local governments were appointed in 1999. Supporting innovation became one of the regional authorities' main tasks which intensified along with European integration processes (Heffner, Klemens, 2017a)

Activities undertaken in Poland in the last ten years to stimulate the development of innovation and entrepreneurship brought growth of numerous and varied in terms of their offer business support institutions, thereby creating business-friendly environment. Expenditure for research and development is increasing and employment in the private sector's R&D is also on the rise (Klemens et al., 2017). A stable regional and innovation development policy requires adequate tools, which include development strategies, among others. However, how do decision-makers understand the concept of co-operation between the main players of regional development? Which companies are willing to co-operate? The purpose of this paper is to attempt to answer the above questions.

The paper consists of three parts. This part presents the concept of strategic thinking and the significance of strategy in regional development. The role of innovation strategies in regional development are the main focus. The second part specifies the phenomenon of co-operation, its relevance, forms and types. Key definitions associated with co-operation are presented. The third part demonstrates the results of the conducted study based on analysing Regional Innovation Strategies in terms of use of the wording related to co-operation.

---

\* PhD Marzena Szewczuk-Stępień, Tel.: +48 884 848 422; e-mail address: m.szewczuk-stepien@po.opole.pl  
PhD Brygida Klemens, Tel.: +48 606 44 80 67; e-mail address: b.klemens@po.opole.pl

The article was developed based on a *desk research* analysis of secondary data (Polish and foreign literature analysis) as well as empirical studies (analysis of the contents of 15 regional innovation strategies with the use of the *text mining* technique).

## 2. Significance of strategy in regional development

Organisations plan their activities to achieve the assumed goals. The essence of strategic planning is to base activities on distinctiveness, unique advantages, individual way of viewing the surroundings, only then we can speak of building a competitive position (Obłój, 2014).

An organisation management system, e.g. territorial unit or economic sector, can also be used as an element of credibility or predictability. The potential for co-operation is also built this way: firstly, specification of goals authenticates the policy in the eyes of potential partners, and secondly, an established development policy allows for elaborating common fields of interest and combining efforts to ensure effective task execution (MRR, 2012).

The Cohesion Policy 2014-2020 was described in the Europe 2020 document. It is a strategy aimed at growth, which promotes an smart and sustainable economy favourable to social inclusion. These three complementary priorities can help achieve high level of employment, efficiency and social cohesion.

In each of the above areas, the EU member states specified their own aims and developed a series of planning documents, including strategies towards smart specialisation (RIS3 strategies).

These strategies are integrated, local programs of economic transformation, which realise the following assumptions: a) establish innovation as the priority for all nations/regions; b) orientate support within the policy and investments towards key challenges and needs to ensure knowledge-based development; c) utilise strengths, competitive advantages and the nation's/region's potential for excellence; d) support innovation and striving to stimulate investments in the private sector; e) involve partners and encourage innovation and experimentation.

The premises of the RIS3 policy include series of elements that emphasise the key role of co-operation, including sharing experiences, uniting as part of a shared vision (networks of co-operation), openness to external relations (e.g. knowledge triangle, clusters), related activities with higher added value (collaboration, co-operation, partnership, consortiums), achieving synergy (common fields of interests, combining efforts), among others (Guide, 2012) (Foray et al., 2009). The vast majority (15/16) of Polish regions possesses their own RIS3. Only the Pomorskie voivodeship abandoned developing the document, however the essence of the addressed notions was included in the Pomorskie Voivodeship Development Strategy 2020 elaboration (due to the adopted research assumptions indicating to the analysis of the RSI document, the aforementioned strategies were not taken into consideration).

The RIS3 documents were developed in 2010-2016 with an expiry date of 2020 to support an effective implementation of the voivodeship development strategies in terms of innovation, research, development and entrepreneurship. The concept of smart specialisation emphasises development based on R&D works and innovation and uses the region's endogenous competitive advantages. In general, the documents were developed in accordance with the recommendations of the European Commission, which emphasises the development of knowledge-based economy requires determination of the so-called smart specialisations.

## 3. Concept of co-operation in regional development

The analysis conducted in the latter part of the paper uses wording (and its variants) that most often concern the essence of co-operation of various regional development players: golden triangle (triple helix, quadruple helix), synergy, cooperation, partnership, complicity, network of co-operation, clusters, producer groups, consortium, co-competition, co-opetition, collaboration, co-production, combining of efforts.

The co-operation of various regional development actors is often described in subject literature by using symbols of the so-called golden triangle or triple helix. Regardless of the symbol used, its main components include: private sector, public sector and the R&D sector (including universities). Gorzelak et al. (2006) points out a somewhat different division in which the golden triangle's composition consists of enterprises, R&D field (universities, technology parks, business incubators) and supporting institutions banks, *venture capital*, local government units, regional development agencies, among others). Independently of the components, the golden triangle concept balances itself with the structure of regional innovation systems, because both of them feature interactions in the region players' environment, which provide good conditions for the creation and stimulation of innovative processes (Głuszczyk 2011, p. 110).

H. Etzkowitz and L. Leydesdorff (2001) used the triple helix model to present various behaviours in economic, social and cultural networks, and particularly demonstrating cluster networks. The triple helix is also visualised as three overlapping circles (private, public sector, R&D) and their common section presents the scope of the trilateral co-operation network (Etzkowitz, Leydesdorff, 2000). This system is a balanced configuration, in which universities become partnered with industry and the public sector, and sometimes become the leader of various types of initiatives (Ejsmont et al., 2016, pp. 13-14). Due to the fact that there are many regional development players, the triple helix model has evolved in time. Currently, we can encounter the Quadruple Helix (Carayannis, Campbell, 2011), Quintuple Helix (Carayannis et al., 2012) or even Hexagon Helix (Frankowska 2012) concepts.



When considering co-operation with the widely understood business, we cannot omit the phenomenon of synergy, which is broadly described in subject literature. It points to the ability of co-operating entities to create higher value than each of them would be able to achieve by acting independently (Jonek-Kowalska 2007).

Co-operation is the ability of creating relations and collaboration, ability of executing tasks as a team, working to solve common problems and achieve mutual goals. Co-operation is a condition required for effective functioning of entities on the market. When considering co-operation, we must not only consider the entities that realise it, but also their market situation, quality of co-operative relations and mainly the effect of synergies created as result of their mutual activities. In subject literature, it is possible to find many types of co-operation, however regardless of its type (a popular form includes consortiums which are established to achieve a particular goal, do not require formal registration, but only conclusion of an agreement by its participants) numerous experiences show that relations and contacts between entities nullify the limits in knowledge access, allow for using good and reliable solutions, which in turn contributes to the generation of new ideas and improves the entities' global competitiveness (Szewczuk-Stepień, 2014, 175-176), (Szewczuk-Stepień, Dymek, 2015).

Regional policy conducted based on strong co-operative systems favours improving the quality of life of citizens, supports entrepreneurship and strengthens the region's reputation. Weakness of the system also weakens the region's position. On the other hand, it is possible to observe that a better economic growth of a region makes the formation of regional networks of relations and creation of partnerships between organisations easier. Vice versa, the lower the growth rate, the weaker the relations between organisations. The relations are also more individualised and are often characterised by lack of trust or hostility (Górzyński 2006, p. 8).

Global economy imposes the need to function in various types of networks associating various economic or regional development players. In subject literature, Castells is viewed as the precursor of contemporary network relations. He observed that the current economy should be viewed as a network affected by attitudes deriving from social, economic and technological changes (2007, p. 267). The aspect that distinguishes business co-operation networks is the unlimited number of members, territorial range or organisational and legal form. A network also becomes core of an innovation system, because it provides good conditions for creating innovation (Herliana 2015, pp. 151-160).

A co-operation network can be understood as a specific form of relations between economic players, based on co-dependencies, co-operation and trust. A well operating network generates a series of advantages for its members, i.e. increase in mutual trust, deepening of social capital, mitigation of social and economic tensions, provision of legal and organisational aid, transfer of knowledge and information (Klemens 2015a, pp. 46-61). A network's characteristic feature is its long-term pro-partnership approach which exceeds the field of single transactions (Ratajczak-Mrozek, Herbec 2014, pp. 30). Nowadays, it is impossible to function outside of a relation network. The process of building an effective co-operation network requires active engagement of its members, which is why understanding the importance of this phenomenon by public decision-makers is so important. Their representation in strategic documents suggests that the decision-makers are aware of the role and significance of creating a positive environment for developing co-operation and make all possible efforts to create favourable co-operative activity conditions for establishing relations and creating values impossible to achieve in case of isolated entity activities.

A characteristic co-operation network form is a cluster which is characterised by spatial concentration and strong co-operative relations. Clusters are a phenomenon formed mainly by the market, by their creation or development can also be stimulated by a suitable policy of supporting such structures (Klemens 2018).

A specific co-operation network form are producer groups which concern collaboration in agriculture and are created to adapt the sales of one's food products to the demand requirements through, e.g. organising supply, common use of machinery, searching for common distribution channels (Wiatrak 2015).

Another related phenomenon is collaboration which plays an increasing role in economic and regional development, including international and trans-border terms. It can be understood as the entirety of understandings concluded with other organisations with simultaneous maintenance of one's independence. It ensures the coordination of common goals, thereby allowing to complete the executed tasks (Ejsmont et al., 2016).

Bengtsson and Kock define co-opetition as a process consisting in a simultaneous clash of two opposite streams of relations: competition and co-operation (2000), in which the parties are competing with each other despite the co-operation (Lado et al., 1997). However, the longer their relations are, the stronger their inclinations towards co-operation and the better the advantages (Cygler 2013).

Collaboration brings a series of advantages, as it provides the possibility of exchanging information, mutual problem solving or mutual learning, among others. It also means that various stakeholders achieve their own goals or common goals in agreement with one another by coordinating their decisions, attitudes and behaviours. Due to the above, collaboration in strategic management is viewed as a mean to achieve the organisation's goals. Collaboration is based on the assumption that given organisation members can achieve goals that are impossible to achieve by each of them individually (Stanienda, 2012).

Co-production is a specific form of co-operation based on the production (at least to a certain extent) by local community members of public services and providing such services independently of various levels of public authorities, with simultaneous maintenance of public financing and legal regulations (Pestoff et al., 2006). The main axis of existence of co-production is the understanding that without the citizens' active participation, the capabilities of public administration to ensure access to adequate quality of public services are substantially limited. For the local

government, co-production becomes the possibility of building the desired social attitudes, i.e. more openness, better communication, mutual trust, willingness to co-operate or pride from engagement in the region's development. It is therefore a specific form of co-operation (Heffner, Klemens 2017b).

The forms of co-operation presented above seem to be key in terms of regional development, because they favour effective knowledge transfer and contribute to the proliferation of innovative activities (Szewczuk-Stępień, 2016).

#### 4. Data analysis

In the *text mining* process, data is extrapolated from text documents written in the native language. In order to conduct a text analysis, documents should be developed in a specific format. Information acquisition mechanisms are based on the attempt to match the models determining the type of sought content to particular text fragments. The easiest model is the collection of key words. During next step - document browsing, the researcher uses automatic finding of the inflection base, i.e. bringing forms and inflections of a given word to its basic form. In this case, it is necessary to have a list of synonyms with the same or very similar meaning, but not directly derived from the same basic forms. The effect of document browsing is the generation of the number of terms present in the given document. The analysis of the number of terms in documents features the creation of a term frequency matrix (Kuligowska, 2008).

The extraction of information conducted as part of the study was based searching for a specific set of terms identified earlier as key words exhibiting the concept of co-operation (they are presented in the paper's paragraph 3). Each of the 15 strategy documents was browsed with consideration of the inflection base, forms and inflections of the 14 terms specified above. Then, we noted the number of terms present in each document and created the term frequency matrix.

The following terms were the most common: co-operation (1981), clusters (839), co-operation network (682), partnership (505) and collaboration (317). The following terms were poorly represented: consortium (141), synergy (68), collaboration (35) golden triangle (14), producer groups (11), complicity (5), combining of efforts (1). The terms of co-opetition and co-production are not present in the analysed documents. For the purpose of further analysis, we evaluated the studied population (RIS3 documents) with reference to the average frequency (assumed value of 307 terms) and presented the collected results on a radar chart (Fig. 1).

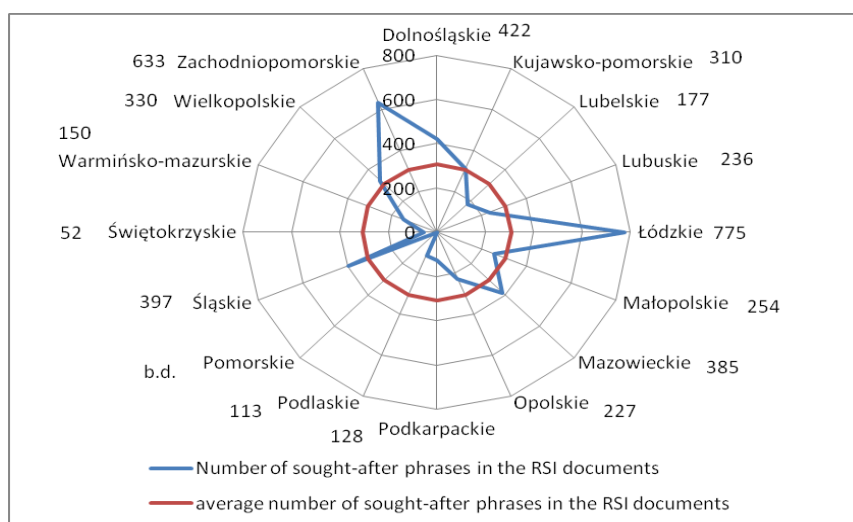


Fig. 1. Comparison of the presence of sought-after phrases with the average value calculated for all documents  
Source: own elaboration

When comparing the number of sought terms in particular RSI documents with the average value estimated for all documents, we observed that 7 out of the 15 analysed documents are characterised by higher frequency of terms associated with co-operation. The ranking leader is the document developed in the Łódzkie voivodeship (775 terms), whereas the terms were least used in the RSI of the Świętokrzyskie voivodeship (52 terms).

From the 14 terms identified in the study as key words specifying co-operation, the five most common terms included the following: co-operation, clusters, co-operation network, partnership, collaboration. The detailed distribution of occurrence in the regional profile is illustrated on the chart in Fig. 2. It is clear that particular innovation strategies feature substantial differences in the frequency of terms referring to co-operation and the emphasis on its specific forms, e.g. clusters play a significant role in strategic thinking in the Dolnośląskie, Łódzkie, Mazowieckie, Śląskie or Zachodniopomorskie, and a smaller role in the Kujawsko-Pomorskie or Warmińsko-Mazurskie voivodeships.

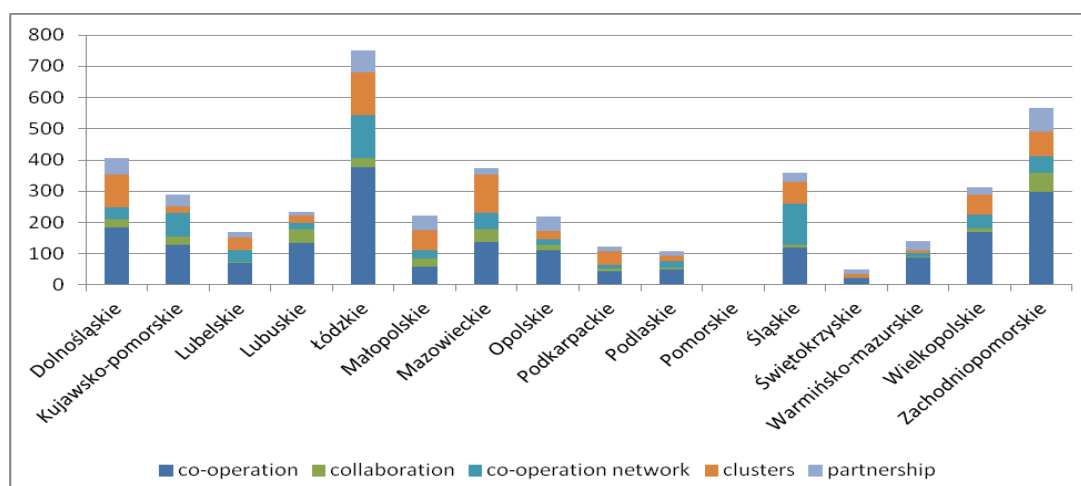


Fig. 2. Presence of sought-after words that are most common in the RSI documents  
Source: own elaboration

## 5. Final conclusions and recommendations

The conducted analysis of the RSI documents in terms of the words referring to co-operation demonstrates that each existing strategy pays particular attention to this phenomenon.

However, we can observe substantial differences in the approach to co-operation. Firstly, the intensity of derivative words related to co-operation varies depending on the given document. It can be concluded that despite the fact that regional authorities see the need for and significance of co-operation, they view it with various intensity and the meaning of this phenomenon varies depending on the region. Secondly, co-operation is well represented in strategies, but in terms of derivative or supplementary phenomena, the following phenomena are well recognised: clusters, networks of co-operation, partnerships, whereas the following are weakly identified: consortiums, synergy or producer groups. The fact that not many documents refer to the phenomenon of a golden triangle, which is important from the point of view of co-operation, is especially disconcerting. The terms of co-opetition or co-production, based in the broader range of terms characterising co-operation, were not used at all.

Currently, intense work is underway on the development of strategic documents for the next EU programming period (2021-2027). It is a good time for decision-makers to verify the current approach, surveying the entire spectrum of terms associated with establishing co-operation and consider including a wider range of co-operation forms by specifying them directly in the strategic documents. Precise entries and explicit indications will surely translate into specific programs, projects and tasks in regions. Co-operation (regardless of the type of partners) brings substantial benefits for all parties involved, consequently the creation of conditions for establishing, strengthening and developing co-operation should be an important part of regional development programming.

## References

- Bengtsson M., Kock S., *Coopetition in Business Networks – Cooperate and Compete Simultaneously*, „Industrial Marketing Management” (ISSN 0019-8501), Vol. 29/, September 2000, p. 411, (2000).
- Carayannis E., Campbell D., *Open Innovation Diplomacy and a 21st Century Fractal Research, Education and Innovation (FREIE) Ecosystem: Building on the Quadruple and Quintuple Helix Innovation Concepts and the “Mode 3” Knowledge Production System*, Springer Science + Business Media, LLC (2011).
- Carayannis, T.D. Barth, D.F. Campbel, *The Quintuple Helix innovation model: global warming as a challenge and driver for innovation*, „Journal of Innovation and Entrepreneurship”, (2012).
- Castells M., *Spółeczeństwo sieci*, Wyd. PWN, Warszawa (2007).
- Cygler J., *Korzyści kooperencji - oczekiwania i efekty*, „Organizacja i Kierowanie” nr 5(158), (2013).
- Ejsmont A., Klemens B., Moczala A., *Klasy - kooperujące i konkurujące organizacje sieciowe*. Wyd. Texter, Warszawa (2016).
- Etzkowitz H., Leydesdorff L., *The dynamics of innovation: from national systems and “Mode 2” to a Triple Helix of university-industry-government relations*, „Research Policy”, vol. 29, no 2, s. 109–123, (2000).
- Etzkowitz H., Leydesdorff L., *The Triple Helix – University – Industry– Government Relations: A Laboratory for Knowledge Based Economic Development*, EASST Review, Vol. 14, (2001).
- Foray D., David P.A. Hall B.H., *Smart Specialisation: the concept*, Ch.3 in *Knowledge for Growth: Prospects for science, technology and innovation*, Report, EUR 24047, European Union, (2009).
- Frankowska M. (ed.), *Tworzenie wartości w klastrze*, PARP, Warszawa, s. 29-30, (2012).
- Głuszczyk D., *Regionalna strategii innowacji województwa dolnośląskiego a idea podmiotów złotego trójkąta*, [w:]

- Prace Naukowe Uniwersytetu Ekonomicznego, red. S. Korenik, Z. Przybyła, nr 152, Wrocław (2011).
- Gorzelak G., Bąkowski A., Kozak M., Olechnicka A., *Polskie regionalne strategie innowacji: ocena i wnioski dla dalszych działań*, Regional Studies Association - Sekcja Polska, Warszawa, s. 20, (2006).
- Górzyński M., Pander W., Koć P.: Tworzenie związków kooperacyjnych między MSP oraz MSP i instytucjami otoczenia biznesu, PARP, Warszawa 2006.
- Guide to Research and Innovation Strategies for Smart Specialisation (RIS 3), European Commission (2012).
- Heffner K., Klemens B., *Czynniki innowacyjności polskich regionów*, [w:] Prace Naukowe Uniwersytetu Ekonomicznego we Wrocławiu, *Regiony, metropolie, miasta*, nr 467, red. A. Zakrzewska-Półtorak, P. Hajduga, M. Rogowska, Uniwersytet Ekonomiczny we Wrocławiu, str. 189-201, (2017a).
- Heffner K., Klemens B., Koprodukcja usług publicznych na obszarach wiejskich w Polsce, *Studia Obszarów Wiejskich*, tom 47, Warszawa, s. 7-20, DOI <https://doi.org/10.7163/SOW.47.1> (2017b).
- Herliana S., Regional Innovation Cluster form Small and Medium Enterprises (SME): A Triple Helix Concept. *Procedia - Social and Behavioral Sciences*, 169, (2015).
- Jonek Kowalska I., *Efekty synergii w działalności przedsiębiorstwa* [w:] *Efektywność - rozważania nad istotą i pomiarem*, Prace Naukowe AE we Wrocławiu, Wrocław, nr 1183, (2007).
- Klemens B., Cluster development policy in Poland [w:] *Proceedings of the 31st International Business Information Management Association Conference (IBIMA). Innovation Management and Education Excellence through Vision 2020*; K. S. Soliman (EDIT.); International Business Information Management Association (IBIMA); Milan, Italy, pp. 6600-6610, (2018).
- Klemens B., *Benefits from cluster initiatives for entrepreneurs and other actors of cluster structures*, [in:] *Ekonomikos Vystymasis: Procesai ir Tendencijos, IV-osios tarptautinės mokslinės-praktinės konferencijos, įvykusios Vilniaus kolegijos Ekonomikos fakultete 2017 m. balandžio 26 d., medžiaga*, Vilnius, pp. 154-162, (2017).
- Klemens B., *Wpływ kapitału społecznego i sieciowania na rozwój innowacji wśród przedsiębiorstw*, [w:] *Efektywny transfer wiedzy z nauki do przemysłu w województwie opolskim. Uwarunkowania skutecznej współpracy*, red. K. Malik, Ł. Dymek, Wydawnictwo DIFIN, s. 46-60, (2015).
- Klemens B., Derlukiewicz N., Mempel-Śnieżyk A., *Boosting innovation and entrepreneurship in Polish economy*, [w:] *Biblioteka Regionalisty*, nr 17, Uniwersytet Ekonomiczny we Wrocławiu, Wrocław, (2017).
- Kuligowska K., Lasek M., *Eksploracja danych tekstowych (text mining) w przedsiębiorstwie*. *Studia i Materiały Polskiego Stowarzyszenia Zarządzania Wiedzą*, T. 13, s. 126-131, (2008).
- Lado A.A., Boyd N.G., Hanlon S.C., Competition, Cooperation, And the Search for Economic Rents: A Syncretic Model, „Academy of Management Review”, Vol. 22, No. 1, pp. 110–141, (1997).
- Oblój K., *Strategia organizacji*, PWE, Warszawa, (2014).
- Pestoff V., Osborne S.P., Brandsen T., *Patterns of co-production in public services: Some concluding thoughts*, *Public Management Review*, 8, s. 591–599, (2006).
- Planowanie strategiczne, poradnik dla pracowników administracji publicznej*, MRR, Warszawa (2012).
- Ratajczak-Mrozek M., Herbeć M., Znaczenie podmiotów usługowych dla meblarstwa w Polsce - perspektywa relacji sieciowych i współpracy, *Studia Oeconomica Posnaniensia*, vol. 2, nr 1/262, (2014).
- Stanienda J., *Strategia kooperacji w klastrach*, Zeszyty Naukowe Małopolskiej Wyższej Szkoły Ekonomicznej w Tarnowie, t. 20, nr 1, (2012).
- Szewczuk-Stępień M.: Współpraca podmiotów gospodarczych oraz innych partnerów w realizacji przedsięwzięć innowacyjnych. Studium województwa opolskiego – stan, szanse i bariery [w:] *Identyfikacja współczesnych wybranych wyzwań w zarządzaniu organizacjami w środowisku realnym i cyfrowym*, Foltys J., Adamska M. (red.), Oficyna Wydawnicza Politechniki Opolskiej, Opole 2014.
- Szewczuk-Stępień M., Dymek Ł., *Uwarunkowania współpracy gospodarczej- możliwości adaptacji wybranych modeli* [w:] *Projekty lokalne i regionalne – rola kompetencji*, Brandenburg H., Sekuła P. (red.), Uniwersytet Ekonomiczny w Katowicach, s. 102-115 (2015).
- Szewczuk-Stępień M., *Wsparcie procesu komercjalizacji wiedzy i integracji środowiska naukowego z otoczeniem gospodarczym*, *Barometr Regionalny. Analizy i Prognozy*, tom 14, nr 4, Wyższa Szkoła Zarządzania i Administracji w Zamościu, s. 99-105 (2016).
- Wiatrak A.P., Grupy producenckie jako forma więzi w agrobiznesie, "Problemy Zarządzania", vol. 13, nr 1(50), (2015).
- Regional Strategic Documents in Poland (RSI).

## Managerial Concerns for the Exit of 1929-1933 Economic Crisis in the Jiu Valley Coal Mining Industry

Mircea Baron<sup>a</sup>, Oana Dobre-Baron<sup>a\*</sup>

<sup>a</sup>*University of Petroșani, Str. Universității nr. 20, 332006, Petroșani, Romania*

---

### Abstract

We are trying to present in this study some of the preoccupations existing in the Jiu Valley so that the coal mining from this region to effectively respond to the challenges of the economic crisis of 1929-1933.

We are observing, from a management point of view, the application of the principles of “rationalization”, many of the taken measures being dictated by the more or less subjective capacity of Romanian society to absorb the basic production of mines, coal and the necessity of dealing with the income-expenditure ratio, without which the largest part of production capabilities could not maintain its activity.

“Rationalization” has entailed an intellectual and material effort and has consequently created a modern technical basis and, implicitly, the continuation of mining activity in this region and the establishment of the Jiu Valley as the most important carboniferous basin of Romania until the 1990s.

*Keywords:* Jiu Valley; coal mining; mining companies; economic crisis; rationalization

---

During 1929-1933 the global economy would be traversed by an economic crisis of overproduction which would also manifest in the Romanian economy. Mining in general, with the significant exception of gold and silver mining, would enter a crisis, the mining industry and, implicitly, Jiu Valley mining supporting the consequences of imbalances produced in the Romanian economy.

The crisis in the mining industry begins as early as 1927, in the following conditions: the Romanian economy, being in a recession, was incapable of absorbing the entirety of coal production, and the main consumer, Romanian Railways, would reduce its demand for coal and, at the same time, acquire increasingly large quantities of lignite and brown coal, to the detriment of Jiu Valley superior coal; competition with other energy sources manifests itself: petrol (heavy fuel oil (HFO)), natural gases, wood and hydro power, being either less polluting or cheaper, or easier to use; the carboniferous industry is incapable of finding, with notable exceptions, far larger domains which utilize its product and the need to develop technologies which increase burning efficiency etc. (Analele Minelor din România (further A.M.R.), XII, 1929, nr. 5, p. 224-225)

Industrial carboniferous mining in the Jiu Valley, which has its beginnings in the end of the 1860s, the first known production, of 853 t, being obtained in 1868, 150 years ago, would reach maturity in the interwar period.

In the first interwar years, together with the achievement of the Great Union of 1918 and the incorporation of Transylvania in Romania, with geostrategic and legislative changes of 1923-1924, a process of “nationalization” of foreign capital is created in Jiu Valley mining, which determines the creation of new mining companies, in which Romanian capital comprises a majority: the “Petroșani” Company, in operation from the 1st of January 1921, having a social capital of 100 million lei, rising in succession up to 820 million lei in 1927, through the reevaluation of capital, and which overtakes the Jiu Valley actives of the “Salgótárján” Company; the “Lupeni” Company, which started operating on the 1st of January 1925, with a 400 million lei capital, which rose in 1927 to 590 million lei, formed mainly from Jiu Valley actives of the “Uricani-Valea Jiului” Company; the “Valea Jiului de Sus” Company, property, in equal proportion, of, from now, the “Petroșani” and “Lupeni” Companies. At the same time, through the application of the provisions of the Law regarding commercialization and control of State enterprises of the 7th of June 1924, Lonea State Mines are commercialized and, from the 1st of January 1926, the “Lonea” Company would be created, with a 180 million lei capital, of which 150 million lei are State shares, and 30 million lei are private capital, mainly the one involved in the creation of the “Petroșani” and “Lupeni” Companies. Furthermore, on the 1st of July 1926 a small mining company would be created, the “Sălătruc” Company.

Table 1. Romanian Railways fuel consumption during 1926-1934

Year	Energy source						
	Jiu Valley	Pit coal	Coal	Total	% Jiu Valley coal from total	HFO	Wood
			Lignite and brown coal				
			t				m <sup>3</sup>
1926	1.292.385	10.060	775.072	2.077.517	62,21	295.804	387.446
1927	1.400.625	1.968	835.552	2.238.145	62,58	263.615	185.998
1928	1.350.610	4.411	781.383	2.136.404	63,22	286.203	176.570
1929	1.332.368	574	770.071	2.103.013	63,35	287.476	152.261
1930	1.046.573	-	546.025	1.592.598	65,71	299.997	98.613
1931	952.974	37.252	451.595	1.441.821	66,09	295.556	60.695
1932	822.201	36.388	293.531	1.152.120	71,36	325.498	32.003
1933	780.897	23.782	326.166	1.130.845	69,05	295.997	21.800
1934	777.953	36.383	505.881	1.320.217	58,93	239.170	19.584

Source: Lăzărescu I.M., *Întrebuințarea cărbunilor la C.F.R.*, Miniera, XVIII, 1943, nr. 3, p. 80

As was previously said, the economic crisis, with all of its consequences, would affect coal mining in the Jiu Valley, but what must be emphasized is the fact that, beyond problems of a social nature, which have created a major discomfort to an important part of the workforce, we are currently observing the most important transformations of an organizational, and especially technical and technological nature. These transformations, some which started before the economic crisis, and others which were continued after 1933-1934, and which were thought out and realized by management which has proven itself knowledgeable and performing, would define coal mining in the region for a long period of time, and are contained in what in the era was called *rationalization*. Rationalization mainly sought to lower material costs through better organizing of work and through renewal of fixed capital on the basis of new techniques which allowed a rise in work productivity, and the mining companies of the Jiu Valley would be capable of conducting a policy of major investments.

Eng. Ioan M. Lăzărescu, talking in 1941 in his paper *Cărbunii în economia românească*, arrives at the conclusion that, "the problem of rational use of coal in Romania has been brought up since 1926, meaning in a period in which almost all coal producing nations in Europe went through an acute crisis. The Romanian coal industry, in particular, has been, over the past 15 years, in a unique situation, for it was competing with other fuels which were fairly widespread in the country: HFO, natural gases and wood. It had to make a large effort to sustain itself and to resort to a series of measures meant to ensure a return close to that of the other fuels: 1. Reducing cost price to a minimum, in order to ensure that diffusion is as high as possible in relation to HFO and natural gases in the industry and to wood in household consumption. In order to achieve this goal intensification of the mechanization of extraction, rationalization of exploitation and its concentration were resorted to; 2. Improving the quality of coal meant for consumption, improvements realized through plants for prepaning, sieving and washing, through modern agglomeration and briquetting plants; 3. Improving coal usage conditions at Romanian Railways – the main client of the coal mining industry – in industry and in household consumption" (Miniera, XVI, 1941, număr unic, p. 15-18).

Here we could add the steps relating to the concentration of capital, being created economic entities with a financial, material and human force capable of dealing with market competition and, why not, for cancelling competition which could become a disruptive factor, and not a stimulating one.

Even though we are talking about several mining companies in the Jiu Valley, the fact that they conducted the same type of activity, with the same finality, that they had similar internal organizational structures, that there were close relations between the companies through the origin of invested capital, through the presence of the same people in the leadership of the companies, and, last but not least, the need to efficiently respond to stimuli, especially random external and internal factors, would gradually determine a process of concentration in the entire basin which could ensure a larger return of capital and also an optimization of productive activity.

The artisan of this process would be Eng. Ion E. Bujoiu, CEO of the "Lupeni" Company from the 1st of January 1925 and of the "Petroșani" Company from the 15th of November 1927, his proposals regarding the fusion of the two companies being discussed inside the talks carried between the Romanian Group of shareholders, represented by the Romanian Bank, and the Hungarian "Salgo-Commerce" Groups and "Urikány-Budapest" of the shareholders. The talks would end favorably (Serviciul Județean Hunedoara al Arhivelor Naționale (further SJANHD), *Fond Societatea „Petroșani”. Direcțiunea Generală. Consiliul de Administrație*, dos. 2/1930, f. 23-24), permitting the closing at the end of 1930 of a principle accord regarding the fusion of the "Petroșani" and "Lupeni" Companies. As such, the idea that the fusion brought not only important savings in the total costs generated by the enterprises, through the removal of the different administrations, but also a reduction in return costs through the possibilities of a large merged enterprise to conduct studies and make improvements in the organization of extraction, was accepted.

From a technical point of view, the fusion presented the advantage of the adoption by all of the mining sites of principles proven to work in certain places, of standardization of working methods, of mutual help and of the organization of all principal and secondary mining sites; the mining sites could be reunited – closing some mines if need be – in a few mining groups, each group, built on geographical, geological and technical criteria, being considered a technical unit equipped with all necessary accessories for meeting production goals in good condition; supersized power



plants of the two Companies would be tied together, one of them being closed; an immediate concentration of far too large central workshops of the different groups, a unit named Petroșani Central Workshops being created, which should be able to produce mining machinery and tools; the electromechanical service and the construction service would be concentrated and the colonies maintained (SJANHD, *Fond Societatea „Lupeni”*. *Direcțiunea Minelor*, dos. 166/1930, f. 1-5).

In order to make the accord operational, an extraordinary general assembly of the two mining companies was held on the 29th of May 1931, in which it was decided that the “Lupeni” Company would be dissolved and fused (Monitorul Oficial, II, nr. 133/12 iunie 1931, p. 7481-7485).

The extraordinary general assembly of the “Lupeni” Company shareholders held on the 29th of May 1931, would unanimously approve: the fusion of the “Lupeni” Company with the “Petroșani” Company; the assets and liability of the “Lupeni” Company would be transferred through the effect of the fusion to the “Petroșani” Company, and personnel of the “Lupeni” Company would be transferred to the employment of the “Petroșani” Company, in the same conditions in which it is situated in the “Lupeni” Company; through the effect of the fusion with the “Petroșani” Company, the “Lupeni” Company would cease its existence from this moment (SJANHD, *Fond Societatea „Lupeni”*. *Direcțiunea Minelor*, dos. 169/1931, f. 1-2).

The extraordinary general assembly of the “Petroșani” Company shareholders held on the 29th of May 1931, would decide the fusion of the “Petroșani” Company with the “Lupeni” Company through the incorporation of the entirety of assets and liability of the “Lupeni” Company to the “Petroșani” Company, based on the balance sheets of the two societies at the 31st of December 1930; the growth of social capital of the “Petroșani” Society, from 820 million lei to 1.410.000.000 lei, meaning with 590 million lei, a sum which represented the “Lupeni” Company capital; the modification of articles 5, 6, 8, 9, 11, 13, 15, 25, 29 from the Statutes of the “Petroșani” Company (Societatea Petroșani, *Statute. Modificate în Adunarea Generală Extraordinară din 29 mai 1931*, Tiparul Românesc, București, 1931; Monitorul Oficial, II, nr. 133/12 iunie 1931, p. 7483-7484), and the modification of the statutes of the company’s Pension House (SJANHD, *Fond Societatea „Petroșani”*. *Direcțiunea Generală. Consiliul de Administrație*, dos. 1/1930, f. 5-6).

The newly formed “Petroșani” Company, having its social centre in Bucharest, would be the largest producer of coal of the country and, at the same time, the third largest industrial corporation by capital, initially having the following organizational structure: the General Direction, situated in Bucharest, led by the general director; Mining Groups: Petroșani, Vulcan, Lupeni; the Central Administrative Division of the Jiu Valley/The Petroșani Mining Direction; the Lapoș Mining Exploitation; the Sebeș Forest Exploitation; the General Services Direction (SJANHD, *Fond Societatea „Petroșani”*. *Direcțiunea Minelor. Serviciul Muncă și Salarii*, dos. 9/1932, f. 1-10).

Following the process of capital concentration, the “Petroșani” Company would purchase in 1933 the 10.000 shares of the “Sălătruc” Company, taking over its patrimony and transferring its social centre to Bucharest (SJANHD, *Fond Societatea „Sălătruc”*, dos. 35/1940, f. 556). This way, the “Sălătruc” Company is incorporated technically, organizationally and socially in the “Petroșani” Company and would continue with its support to carry on its extractive operation until January 1941 when an approval by the Ministry of National Economy to suspend mining operations is obtained (SJANHD, *Fond Societatea „Sălătruc”*, 28/1938-1942, f. 7-8).

The “Valea Jiului de Sus” Company would be absorbed by the “Petroșani” Company as well. Because after July 1931 the productive activity in the mining field of the “Valea Jiului de Sus” Company from Vulcan would cease, in November 1942 the General Assembly of the Company would decide the fusion of the “Valea Jiului de Sus” Company with the “Petroșani” Company, through the concession of capital and patrimony (A.M.R., XXV, 1942, nr. 12, p. 256).

In 1929, as a result of the teachings acquired during a study trip in the Ruhr mining region in Germany, Eng. August Buttu from the “Petroșani” Company elaborates a study named *Raționalization in coal mines with a few considerations on the opportunity of mechanization and frontal slopes* (the study will be published later in, A.M.R., XXIV, 1941, nr. 2, p. 27-35; nr. 3, p. 53-62), in which he proposes, among others, quitting coal layers and unprofitable mines and the methodical concentration of operations, possible, however, only after new stoping methods will be adopted. By this logic, the “Petroșani” Company would proceed to close the following mines: West Petroșani (30th of October 1928) (SJANHD, *Fond Inspectoratul Minier Petroșani*, dos. 68 c/1931, f. 10-18); Dâlja/Petroșani (march 1931) (SJANHD, *Fond Inspectoratul Minier Petroșani*, dos. 68 c/1931, f. 5); West Vulcan, East Vulcan, Dr. Chorin (SJANHD, *Fond Inspectoratul Minier Petroșani*, dos. 99/1931, f. 13-24) and “Valea Jiului de Sus” from Vulcan (SJANHD, *Fond Inspectoratul Minier Petroșani*, dos. 99/1931, f. 30) after July 1931 and temporarily suspend the activities of the East Petroșani Mine at the 29th of June 1937 (SJANHD, *Fond Inspectoratul Minier Petroșani*, dos. 106/1937-1938, f.f.), which would then become a sector of the Petrila Mine.

In Lupeni, the program was based on intensifying the production of the Ștefan and Ileana Mines in the 3, 5, 8, 9 layers, after the depletion of higher layers of the Ileana Mine, the closing down of the Carolina and Victoria Mines during a 2-5 year term, meaning after the complete depletion of higher coal layers (SJANHD, *Fond Societatea „Lupeni”*. *Direcțiunea Minelor*, dos. 101/1928, f. 47-48; dos. 68e/1931, f. 13-14; dos. 9/1932, f.f.). Such a process would also occur at the “Lonea” Company. It was thought that the most logical solution regarding concentration would be at Mine III “Jieț” - Mine I Cimpă and II Lonea would be closed down from 1930 – because it presented the largest advantage that the majority of organizational operations were already under way, the coal layers permitting the



application of modern extraction methods, and the coarse coal was in a smaller percentage than in the other two mines (SJANHD, *Fond Inspectoratul Minier Petroșani*, dos. 111/1931, f. 1-5).

Therefore, a process of reorganizing mainly surface activities is taking place, at the same time as the lowering of production capabilities, which has not, however, affected the possibility of satisfying the necessary amount of coal demanded on the market. Inside the “Petroșani” Company, the Petrila, East Petroșani, Aninoasa, and the Lupeni Group mines would remain functional after May 1931, with the present mines, at the “Lonea” Company, Mine III “Jieț”, and there was also the small enterprise of the “Sălătruc” Company from Livezeni, so that, by the end of the interwar period, five mines would operate: Petrila, Aninoasa, Lupeni, Lonea and Sălătruc, the latter being closed down in January 1941.

It was thought that closing down these productive units would not affect the capacity of the Jiu Valley to provide the necessary amount of coal demanded on the market: Mine III Lonea could provide, work being done in two shifts, 500 t coal/day, so a 55% increase relative to May 1931, and the “Petroșani” Company could provide, through the Lupeni and Petroșani mining groups, 5.200 t coal/day, work being done in two shifts, so a 75% increase relative to May 1931. Furthermore, it was determined that, should the expansion of production be necessary, the following mines could be reopened: II Lonea; West Petroșani and Dâlja/Petroșani; East Vulcan; Victoria/Lupeni. It was determined that the existing features allowed the expansion of production capabilities of the Jiu Valley mines with 1.700 t coal/day as soon as necessity would demand it, keeping the advantages of surface concentration (SJANHD, *Fond Societatea „Petroșani”. Direcțiunea Minelor. Serviciul Tehnic*, dos. 1/1931, f. 1-3).

Concentration would make the “Petroșani” Company, which had in its activity, before this process, 15 mines and 32 pits, in 1943 to only have three mines in exploitation, where 14 pits were functioning, among which only four were extraction pits. The effects of concentration can be observed in the quantity of extracted coal/metre of tunnel: in 1928 there were 203,8 km of tunnels at annual production of about 132.355 t of coal, and in 1941, 101,7 km to 186.000 t, so 0,65t/m in 1928 and 1,82 t/m in 1941 (Buttu, 1943, p. 65).

Eng. August Buttu, in the cited study, has also regarded that, in order to optimise activities long-term solutions were necessary, which consisted of, among others: reestablishing discipline and order; lengthening effective work time; rational use of those who did not produce, elimination of those who were useless, unwanted, inadequate; increase and picking of good supervising and control personnel, for the workers as well as for the material and equipment; rising the value of workers through schools; protection of personnel through safety measures, medical service and welfare; equitable wages and bonuses; perfecting mechanical equipment, introduction and use of machinery in mines, applying the principle of: *don't let a man do what a machine can*; methods of general organizing and of exploitation with the application of a large-scale concentration policy, through the introduction of stopes with long fronts, large units of production.

Eng. Ion E. Bujoiu would understand that these measures had to be taken, especially in the increasingly harsh conditions which affected the mining companies in 1929, due to the tripling of mining tax, the lowering quantity of taken coal and the lowering of prices by 8% of supplies to Romanian Railways, the competition of other energy sources, and higher wages. At the made proposals, Eng. Ion E. Bujoiu added the obligation to obtain the amelioration of the amount of coal extracted through the removal of as much sterile as possible and reduction of the percentage of dust, in order to deal with consumer requirements.

From the amount of issues, we will choose just two plans of action: *a.* the introduction of new exploitation methods, based on augmenting mechanization; *b.* sustained preoccupation with ameliorating the quantity of extracted coal. The modernization of exploitation methods, like of the entire productive process of Jiu Valley mining, would obviously entail the development of mechanization, tools and machines being built which would operate underground using electricity and compressed air, being, at the same time, safe for the vicious medium, especially the one with methane, in which they operated.

If at the surface the spread of electricity was universal, three-phase asynchronous engine being an indispensable auxiliary for any machine, steadily electricity has entered the underground: centrifugal pumps; ventilation fans; locomotives with trolleys or accumulators; trolleys for inclines, and in the coalface: oscillating troughs; transporters with rubber bands or scrapers. Even though, in the coalface, pneumatic dislocation tools were prevalent – in 1925 624 pneumatic hole punchers, 38 stoping hammers, 19 hewing machines, 1509 m oscillating troughs (SJANHD, *Fond Societatea „Petroșani”. Direcțiunea Minelor. Serviciul Tehnic*, dos. 4/1925-1932, f. 1) - electricity tends to be used through electrical lighting of the workplace, using fans for secondary ventilation, centrifugal pumps, electrical boring machines, hewing machines, using asynchronous motors etc., such that, in 1929 the “Petroșani” Company consumed 19,9 Kwh/t of extracted coal, the Lupeni Group, which was the most electrified, consuming 34,4 Kwh/t of extracted coal. Furthermore, in 1931, after the Petrila and Lupeni Preparation Stations started their operations, the specific energy consumption of the “Petroșani” Company would be 27,8 Kwh/t of extracted coal. Of course the focus on mechanization and, implicitly, on the introduction of electricity, would favor an increase in the capacity of the Vulcan and Lupeni Power Plants the coal mines consuming a part of the production in order to create secondary energy with a large output (Georgescu-Gorjan, 1933).

The growth of mechanization would allow the introduction, beginning with 1927-1929 in Lupeni, along with the method of exploitation with stoping rooms, the method of exploitation with mechanized stopes with a long 80-120 m front in thin layers, method which would later be applied in the Petrila, East Petroșani Piscu/Aninoasa mines. The use in stopes with a long front from thin layers, of hewing machines, has determined a 50% growth in returns and a productivity of the hewing machine of 96 t/shift, with an 80 m long coal-face (Marian et al., 1969, p. 60).

During 1932-1933 experimenting was done in Lupeni, being later applied at Aninoasa mine, with the following type of exploitation: directional frontal stopes, in layer 3, using a pneumatic embankment, the long front being introduced in the main layer as well (SJANHD, *Fond Inspectoratul Minier Petroșani*, dos. 62/1933, f. 1-3). From 1933, again in Lupeni, in layer 3 the method with transverse front and pneumatic embankment was introduced, followed in 1934-1935 by the selection of coal in the coal-face (SJANHD, *Fond Societatea „Petroșani”. Direcțiunea Minelor. Serviciul Tehnic*, dos. 45/1932-37, f. 180-182).

In 1936 the first horizontal frontal stope started operating in layer 3 at the Lupeni mine, with metallic support under an artificial ceiling made out of planks, the method being extended in 1937 in Lupeni at layer 5, in frontal stopes on the layer's slope. This type of support, with 70 kg metallic pillars supplied by the "Schwarz" company, semi rigid type, with planks, with a strength of 30 t/pillar (SJANHD, *Fond Mina Lupeni*, dos. 28-12/1937, f. 47), would be applied at layer 3 at Aninoasa mine in 1937 and at Petrila mine in 1938 (Giuclea and Oprea, 1969, p. 114-115). It is worth mentioning that augmenting mechanization and introducing new methods of exploitation, which are based on technological progress, would cause advancing speeds in stoping and a growth in productivity, as expected - in 1928 the "Petroșani" Company had 9.926 employees, of which 2.525 were miners, output in the coal-face being 2,226 t, and in 1934 there were 6.484 employees, out of which 1.635 were miners, output in the coal-face being 3,988 t - however, the growth is not spectacular, and after peaking in 1933-1934, output started to visibly decline, which shows us that mechanization helps the effort of the people, but in mining deposit conditions definitively influence the output of machines and of people (SJANHD, *Fond Societatea „Petroșani”. Direcțiunea Minelor. Serviciul Muncă și Salarii*, dos. 2/1935, f. 16).

The second large direction which we were referring to would be represented by the sustained preoccupation for ameliorating the quality of extracted coal, through methods used in the mine: reduction of shooting, selection, manipulation, as well as especially its mechanical preparation. This direction would impose financial and technical actions to ensure a response to the "challenge" which coal buyers imposed and, at the same time, ensure its integral capitalization at a price which should be as convenient as possible (Baron and Dobre-Baron, 2004).

Romanian Railways, which used coal for the production of vaporized water in the locomotive's focus, was the main buyer of coal extracted in Romania and would impose its own policy regarding quantity and quality of the purchased product. Otherwise, the evolution of Jiu Valley mining companies would be decisively influenced by the purchasing policy of Romanian Railways and a part of the realized transformations, especially the qualitative ones, would owe to the requirements formulated and imposed by their most important client. The leaders of these mining societies understood that, in the conditions in which coal is not a renewable source, it is beneficiary that it be exploited rationally and, most importantly, be capitalized in a superior and profitable way.

1930 exploitation programs and the extraordinary operations program for 1930-1931 and 1932 of the "Petroșani" and "Lupeni" Companies provided the concentration of mechanical coal preparation activities in two modern and complex installations, using the "rheo-laveur" system, at Petrila and Lupeni, which would replace the old separations at East Petroșanit, West Petroșani, Vulcan, Lupeni: Victoria and Ștefan (SJANHD, *Fond Societatea „Petroșani”. Direcțiunea Minelor. Serviciul Tehnic*, dos. 25/1932, f. 1-97). The Lupeni plant with a washing capacity of 140 t/h, would be functional from the 18th of February 1931 (SJANHD, *Fond Inspectoratul Minier Petroșani*, dos. 84/1932, f. 1-7), and the Petrila plant, with a washing capacity of 270 t/h, would be functional from the 12th of August 1931 (SJANHD, *Fond Inspectoratul Minier Petroșani*, dos. 54/1931, f. 32).

The beginning was continued and so, at the beginning of the 1940s, the "Petroșani" Company could boast about a complex of coal preparing equipment, unique in Romania, comprised of seven groups: washing plants; drying plants; flotations; water treatment; briquetting; low-temperature carbonization; auto agglomeration (Buttu, 1937, f. 1-26), and which allowed it to deliver a large assortment of coal to its clients (Buttu, 1937, f. 4).

All of these actions and achievements have not only had a financial and technical component, but also a social component. Through all that was achieved, the economic crisis was overcome and, especially, the maintenance of the Jiu Valley industrial complex and the underlining of qualitative competence, which allowed it to keep an economic, technical and social role in the Romanian economy. All of these would not have been possible without those who have been invested in leading the destiny of this industrial complex and who had the managing capacity of thinking about continuity through the imposition of transformations which overlooked all the components of this entity.

## References

- Analele Minelor din România, XII, nr. 5, p. 224-225, (1929); XXV, nr. 12, p. 256, (1942).
- Baron, M., Dobre-Baron, O., *Evoluția prețului la cărbunele vândut Căilor Ferate Române în perioada interbelică*, Sargetia, XXXII, p. 609-622, (2004).
- Buttu, A., *Vues retrospectives sur l'industrie extractive de charbon en Roumanie au cours des dernières 25 années*. A.M.R., XXVI, nr. 4, p. 61-70; nr. 5, p. 85-89, (1943).
- Buttu, A., *Cerințele consumatorilor de cărbuni din România și adaptarea instalațiilor de preparare la aceste cerințe*, în, SJANHD, *Fond Societatea „Petroșani”*. Direcțiunea Minelor. Serviciul Tehnic, dos. 63/1937, f. 1-26, (1937).
- Buttu, A., *Raționalizarea în minele de cărbuni, cu câteva considerații asupra oportunității mașinismului și abatajelor frontale*, A.M.R., XXIV, nr. 2, p. 27-35; nr. 3, p. 53-62, (1941).
- Georgescu-Gorjan, Șt., *Aplicațiile electricității în industria carboniferă*, Buletinul I.R.E., I, nr. 2, p. 229-268, (1933).
- Giuclea, Gh., Oprișă, D., *Susținerea abatajelor în minele din Valea Jiului*, în vol., xxx, „Dezvoltarea tehnicii miniere în bazinul carbonifer Valea Jiului”, edited by, Ministerul Minelor, Oficiul de documentare și publicații tehnice, București, p. 114-127, (1969).
- Lăzărescu, I. M., *Întrebuințarea cărbunilor la C.F.R.*, Miniera, XVIII, nr. 3, p. 80, (1943).
- Marian, I., Iliaș, N., Giuclea, N., Teodorescu, C., *Probleme privind mecanizarea în abatajele din Valea Jiului*, în vol., xxx, „Dezvoltarea tehnicii miniere în bazinul carbonifer Valea Jiului”, p. 59-89, (1969).
- Miniera, XVI, număr unic, p. 15-18, (1941).
- Monitorul Oficial, II, nr. 133/12 iunie 1931, p. 7481-7485.
- Serviciul Județean Hunedoara al Arhivelor Naționale: *Fond Societatea „Petroșani”*. Direcțiunea Generală. Consiliul de Administrație; *Fond Societatea „Petroșani”*. Direcțiunea Minelor. Serviciul Muncă și Salarii; *Fond Societatea „Petroșani”*. Direcțiunea Minelor. Serviciul Tehnic; *Fond Societatea „Lupeni”*. Direcțiunea Minelor; *Fond Mina Lupeni*; *Fond Societatea „Sălătruc”*; *Fond Inspectoratul Minier Petroșani*.
- Societatea Petroșani, *Statute. Modificate în Adunarea Generală Extraordinară din 29 mai 1931*, Tiparul Românesc, București, (1931).

## Optimization of business processes with the use of microlocation tools based on the Industry 4.0 concept

Janusz Wielki<sup>a\*</sup>, Przemysław Koziol<sup>b</sup>

*Opole University of Technology, the Faculty of Economics and Management, Opole, Poland*

*<sup>b</sup> Algeco Polska sp. z o.o., Poznań, Polska*

---

### Abstract

The dynamic development of information technology enables the implementation of tools that improve business processes in enterprises with an unregulated flow path. The use of intelligent systems within the framework of the concept of Industry 4.0 makes it possible to monitor the resources and processes in real time in order to perform efficient inference and modelling of the workspace, shortening in this way the path of implementation. The aim of the article is to analyse the possibility of using microlocation tools in the optimization of business processes. The adopted method of the analysis of literature covering the field of the Industry 4.0 concept and the use of individual case method for Indoorway InSites 4.0 tools allow to present potential benefits for business while their extended recognition may become the basis for further research. Flexible shaping of workspace generates savings due to both the rationalization of the space utilisation and elimination of the phenomenon of hidden waste, which is particularly important for organizations with unregulated process paths. The synergistic benefits of lean management, Industry 4.0 and microlocalization tools are commonly used, and on the market are available intuitive, relatively cheap tools, the implementation time of which does not exceed several hours.

*Keywords:* industrial Internet; Internet of Things; location technologies; business processes improvement

---

### 1. The concept of Industry 4.0: the concept, characteristics and possibilities associated with it

When it comes to the very concept of Industry 4.0, it is possible to indicate quite precisely when it first went public. The term was coined at the Hannover Fair in 2011 and refers to the fourth phase of the industrial revolution (Schwab, 2016). Historically, the first of these phases (Industry 1.0) took place at the end of the eighteenth century (1784) and involved the introduction of a steam machine in mechanical production systems. The next phase of the Industrial Revolution (Industry 2.0) started at the end of the nineteenth century (1870) with the emergence of mass production systems based on the use of electricity. The third phase (Industry 3.0) started at the end of the 1960s (1969). It was associated with the use of electronics and IT systems in the process of further automation of production. Phase four (Industry 4.0) is associated primarily with the possibilities opening in the context of combining the real and virtual worlds, based on the use of cyber-physical production systems (Deloitte, 2015). Other terms used in this context are: Industrial Internet, Connected Enterprise, SMART Manufacturing, Smart Factory, Manufacturing 4.0, Internet of Everything, Internet of Things for Manufacturing or Digital Factory (Cotteleer et al., 2016; Geissbauer et al., 2016a).

There are various definitions of the Industry 4.0 concept. Baur and Wee understand this term just as the next phase of digitization of the manufacturing sector (Baur and Wee, 2015). In turn, according to Geissbauer et al., the concept of Industry 4.0 refers to over a dozen key innovations in the field of information technologies, which in recent years have reached the level of maturity, ready to transform such sectors as energy and production (Geissbauer et al., 2016). According to the PWC this term is to be understood as the end-to-end digitalization of all physical resources and their integration with digital ecosystems created with value chain partners (Geissbauer et al., 2016a). However, for Helbig et al. the essence of the term "Industry 4.0" comes down to incorporating the technical integration of cyber-physical systems into the manufacturing and logistics sphere and the use of Internet of things and Services in the industrial

---

\* Corresponding author. Tel: +48-77-449-88-00; fax: +48-77- 449 88 16.  
E-mail address: Janusz@Wielki.pl.

processes (Helbig et al., 2013). Deloitte, on the other hand, defines Industry 4.0 as a combination of physical and digital technologies that enables the creation of a digital enterprise that is not only completely connected but also capable of more holistic, informed decision-making (Deloitte, 2018).

According to the Deloitte consulting company, it is possible to indicate four features that characterize Industry 4.0. These are (Deloitte, 2015):

1. Vertical networking of smart production systems.
2. Horizontal integration via a new generation of global value chain.
3. Through-engineering across the entire value chain.
4. Acceleration through exponential technologies.

At the same time, it is possible to point to various factors stimulating the development of the Industry 4.0 concept. According to Bauer and Wee these are (Baur and Wee, 2015):

- Exponential growth in the amount of data available and the development of the Big Data phenomenon.
- Development of advanced analytics.
- The emergence of new forms of human-machine interaction, such as augmented reality.
- The advances in information flows between digital and physical world (*digital-to-physical transfer*), for example, 3-D printing.

Schwab, in turn, points to the three categories of *technological drivers* of the fourth industrial revolution i.e. physical, biological and digital. The first of these categories includes such technology megatrends as: autonomous vehicles, 3D printing, *advanced robotics* or new types of materials. In the field of biology, these are advances in the genetic research, *synthetic biology* or the use of 3D technology in medicine (*bioprinting*). As far as digital factors are concerned, these include such technologies as *blockchain*, the technology platforms for the development of the "*on-demand economy*" or the Internet of Things [Schwab, 2016, p. 18]

As mentioned above, the Industry 4.0 concept is based on the use of a whole range of digital technologies that have evolved over the years at an exponential pace and have reached the appropriate level of maturity (Davis and Schwab, 2018). According to the PWC these are (Geissbauer et al., 2016a): cloud computing, mobile devices, IoT platforms, location detection technologies, advanced machine-to-man interfaces, authentication and fraud detection technologies, 3-D printing, intelligent sensors, Big Data analytics and advanced algorithms, multilevel customer interaction and customer profiling systems, the augmented reality/wearables.

At the same time, the data and analytics are indicated as *the core capabilities*. PWC also points out in its report to the three essential possibilities related to the Industry 4.0 concept and "driving" its development. These are (Geissbauer et al., 2016a):

1. Digitization and integration of vertical and horizontal value chains.
2. Digitization of product and service offerings.
3. Digital business models and customer access.

## 2. The phenomenon of endemic waste in organizations with a unregulated flow path

Companies, in order to ensure the value desired by the customer, design and continually refine their business processes through, among others, identification and elimination of all forms of waste, which have an adverse impact on the flow and effects of work (Stenzel, 2007). In well organized enterprises that constantly optimize their flow paths (information, materials, semi-finished products and products paths), a defined process map makes it possible to identify both: the sources of the creation of value added product and waste. The advanced process awareness is characteristic for companies in the such sectors as: automotive, domestic appliances, electronic and electrical, FMCG and food sector. However, also in other branches it is possible to find companies that base their activities on the concept of lean management, usually being leaders in their industry.

Waste is defined as a broad spectrum of activities which do not bring added value to the customer and to enterprises with a unregulated flow path in which lack of lean culture waste is endemic. While in companies with advanced process awareness, the search, reduction and prevention of hidden waste is mandatory, in organisations with unregulated flow path this phenomenon is not unequivocally characterised and therefore subjective, and additionally it can have a decisive impact on the business profitability. Organizations that do not map their own business processes, expose themselves to process gaps, do not integrate their activities with the needs and requirements of the customer, prolong the flow time, and as a result degrade their own accounting liquidity. The lack of stabilisation of flow pathways is typical of enterprises with low level of standardization of operations, work at unstable rates with a small number of repetitive activities, with the need to pay attention to the details of the product, especially in companies where there is no rooted and developed lean culture, regardless of the field of activity. Of course, there are specialized solutions dedicated to e.g. piece- or small lot-producing companies that integrate flows through the use of ERP class systems, e.g. by processing data about the demand, the availability of materials, the technical and technological capabilities of machinery and equipment, and any other information necessary to provide an optimal production plan. However, systems of this class are often unattainable for many small and medium-sized enterprises and their implementation and maintenance is associated with significant costs. From this perspective, it is crucial that in the era of the development of

the Industry 4.0 concept, there are widely available IT solutions on the market that support organizations with unregulated flow path in business optimization by effectively reducing waste within the processes.

### **3. Application of the Indoorway InSites 4.0 platform for multidimensional motion analysis**

One of the providers of smart building solutions in which object navigation and space mapping were used to optimize business processes and usable space, is the Indoorway company, the winner of the final of the national competition for start-ups: PowerUp! by InnoEnergy 2018. Indoorway's algorithms analyze data multidimensionally through the use of the company's location technology Indoorway Hive and a mobile application based on an accelerometer, magnetometer, gyroscope and beacons that enable precise navigation. Obtaining localization accuracy up to 20-30 cm makes it possible to use microlocation to optimize business processes and gives practically unlimited possibilities regarding traffic analysis and, as a result of this analysis - possibilities to shape the workspace. Indoorway company, in addition to comprehensive implementation of the multidimensional motion analysis service, provides a set of tools with the use of which the developers can create proprietary solutions based on indoor navigation. Scalability of the system allows the use of an IT platform in organizations of various sizes, and the authors emphasize that the goal of developing the solution was to create a fast, clear and logical implementation system that can realistically be implemented in several hours. The companies using the InSites 4.0 platform include representatives of the following industries: manufacturing, real estate, finance, transport, IT and others. Currently, the company's development is aimed at commercializing the platform, adjusting the analytics results from Ultra WideBand technology (UWB) to the largest customer groups and conducting the pilot implementations of the new technology.

IndoorS InSites 4.0 tools operate based on UWB technology and Bluetooth Low Energy (BLE) - Bluetooth version 4.0, which eliminates the problem of continuous operation of connected devices, and hence, rapid consumption of battery power from wireless devices. On the basis of BLE, the iBeacon protocol for devices called beacons was developed. Beacons are signal emitters containing an encoded identifier, which can be used by mobile devices (Łyda and Miłosz, 2017). The data from beacons can be used in a variety of applications in advertising, sales and services. Using them in the industry to optimize processes opens new possibilities for shaping space and organization of work. UWB broadband technology is based on sending short-term pulses at a fast rate. UWB devices work at a low power level which eliminates interference with other radiocommunication devices. Low energy consumption makes it possible to build a wireless location system for users. This technology has the ability to penetrate some construction materials (concrete, wood, glass) which is important for estimating the distance of objects and testing their location and tracking inside buildings. This property is also used for indoor positioning because it gives the possibility to determine the distance in the absence of direct visibility (Czopik and Kraszewski, 2014).

InSites 4.0 is a ready-to-implement set of tools based on an in-building location system that uses devices such as tags and hubs. Tags are transmitters, placed on vehicles or machines, and can be a part of the equipment of the employees. Hubs as receivers are mounted on the elements of the facility's infrastructure (walls, ceilings) to collect data about the location of the tested elements. Information about the traffic in space gathered in this way is presented in a user-friendly, online analytical panel. Due to higher reliability and accuracy, ultimately Indoorway solutions will be based only on UWB technology.

The InSites 4.0 platform provides data for multidimensional motion analysis in the following areas:

- traffic analysis,
- heat maps – a workload for working space,
- analysis of the distribution of employees (or guests) in the organization space,
- input/output analysis (room statistics).

Use of data from the above tools makes it possible to identify instability of the process flow, visualize its actual status and not only the hypothetical notion of the status, and constitutes a practical starting point for changing the process elements in order to optimize the process.

The system of control of the employees' movement, regardless of the tools used, arouses a lot of controversy and can be identified with surveillance. Apart from arguments regarding the safety of employees (in the event of evacuation from the workplace, faintness, etc.), microlocation tools can be used to optimize the organization of work by collecting and processing data on, among others, work time in and outside of the workplace and the distance the employees have to cover to carry out specific business processes. The analysis of these data is closely related to defining the process and revealing any traces of waste, especially the waste of motion and the waste of transportation, which in turn improves the functioning of the enterprise in a dynamic environment, increasing its competitive advantage.

Table 1. Time of implementation of platform InSites 4.0 divided into stages (source: own study based on the Indoorway company data).

Industry	Time of realization of the platform implementation						Total implementation time
	Design	Systems assembly	Service training	Modification and customization	Testing and quality control	Final acceptance	
Production	64	16	2	8	8	2	100
Finance & Banking	120	12	2	6	6	2	148
Real Estate (Implementation 1)	1.920	144	8	72	72	8	2.224
Real estate (Implementation 2)	960	72	4	36	36	4	1.112
Consulting for industry	16	16	2	16	2	2	54
Fitness	40	240	40	40	20	20	400
IT	120	12	2	6	6	2	148
Rail transport	8	8	2	4	2	2	26

As part of the analysis, the length of the process of implementation of the InSites 4.0 platform was measured, which affects the real cost of the project. It was found that it depends on the degree of specification of the potential customer's goals. The process proceeded in the following stages:

- customer's request for proposal,
- presentation of the system realizing the assumed goal,
- offers of a trial or end-to-end implementation,
- preparation of implementation (electrical installation, WiFi, server, tags and hubs, space map, infrastructure),
- implementation (map configuration, hardware placement, system commissioning, preliminary measurement),
- system operation tests,
- post-installation service and technical support,
- data analysis.

The above-mentioned stages were consolidated into groups: design, system assembly, training on servicing, modification and customization, testing and quality control, and final acceptance. For the implementations of the InSites 4.0 platform realised by Indoorway company, the implementation times for individual projects are shown in Table 1.

The benefits associated with the implementation of microlocation tools in process optimization include:

- acceleration of tasks realization by shortening paths and improving the effectiveness of the use of space,
- elimination of micro-downtime and reduction of endemic waste,
- quick access to current and actual information on the status of the machinery park, the movement of employees and transport equipment,
- increased security through the use of monitoring devices that inform about dangerous situations (lack of movement, potential collisions, etc.),
- the possibility of expanding the platform and adapting it to the company's dedicated needs,
- obtaining transparent and reliable data on the course of processes, delivered without interference caused by subjective notions,
- precise identification of the availability of equipment, premises, workplace, location of employees and transport equipment.

#### 4. Modelling of the space of process execution based on the data from microlocation tools

It is characteristic for organizations operating in the spirit of lean management to constantly search for waste in processes. Typical for organizations with unstable flow paths is ad hoc, temporary and non-persistent workspace designing based only on current goals. Analysis of motion assisted by modern tools based on the concept of Industry 4.0, acting in the background of actions being carried out, provides a range of information that can be used to model the space of the organization without disrupting the already ongoing process.

Thanks to the use of the Indoorway InSites 4.0 platform it is possible to support the optimization of distribution of the means of labour by, among others:

- analysis of the flow paths and, in particular, the distances to cover in the executed process and the time of the movement constituting process waste, performed by mobile devices in a real enterprises environment,
- current and historical degree of utilisation of work zones, communication spaces, rooms, entrances and other elements of the organization's infrastructure,



- analysis of the activity of individual machines and devices, employees and all the company's resources that create added value in the processes.

The Indoorway's InSites 4.0 platform itself does not provide and does not impose ready-made solutions, but by presenting the collected data in an intuitive way, it can be an effective tool for optimizing business processes in the production, commercial or office space. Figure 1 presents one of many tools within the InSites 4.0 platform – a heatmap, thanks to which it is possible to analyse the degree of utilization of the space of business process implementation in the enterprise.



Fig. 1. Application of Indoorway InSites 4.0 heatmap for analyzing the degree of space utilization (source: Indoorway materials).

The data obtained thanks to the use of the IT platform allow for the analysis of processes in terms of their improvement and optimization. Typical examples of workspace reorganization, which at a relatively low cost often bring quick and visible effects, are, among others:

- application of visualization tools,
- use of supermarkets, consisting in organizing intermediate storage space, in which a constant level of stock of the selected assortments of goods is maintained. This approach, used when there are no fixed levels of orders, reduces the movement of workers to the main warehouse,
- reorganization of the workplace, consisting in changing the arrangement of machines and devices so that the path of the process is simple, logical and short,
- reorganization of the process, consisting in changing the order of performing particular operations, implementing standardization, systematics and segregation at the workstation,
- redesigning and change of spatial layout of workplaces, associated with the change of the location of infrastructure (toilets, kitchens, social rooms, etc.) and workstations in relation to each other, in order to shorten the distances that employees have to overcome to achieve their goals,
- process mapping, through the use of visualization of the course of the process, along with its internal connections, increasing the level of awareness about its shape and the resources involved.

## 5. Summary

According to Deloitte estimates, by 2022 at least 25% (currently 5%) of all microlocation applications will be implemented partly or entirely inside buildings. This increase will be the result of, among others, the emergence of new data processing capabilities that have a significant impact on increasing the location precision within the buildings. Deloitte states that the beneficiaries of these changes will be companies active in the beacons market, and their impact will be felt in all sectors of the economy, from government institutions to manufacturing companies and consumers around the world. Although microlocation is not a new concept, the development of interaction between the user and the application creates a new space for development. Among the active Polish companies in this industry, the most important are Estimote, Infinity, Kontakt.io and Linteri (Deloitte, 2017). Microlocation tools can have a critical impact on the optimization of the implementation space of the processes and on the shape of the business processes in organizations with unregulated flow path, which is the starting point for further scientific research. The subject of the authors' interest remains the in-depth analysis of the real benefits associated with the implementation of microlocation solutions and investigation whether relatively low implementation costs compared to potential revenues can be an incentive for further implementation of optimization platforms (such as Indoorway InSites 4.0) for small and medium-sized enterprises. The key to the change is the increase of the entrepreneurs' awareness that the financial result is influenced not only by the amount of generated revenue, but also by the level and structure of the organization's costs. Eliminating endemic waste is a challenge for all enterprises, and emerging start-ups provide modern tools to support this process.

## References

- Baur, C., Wee, D., *Manufacturing's next act*, <http://www.mckinsey.com/business-functions/operations/our-insights/manufacturings-next-act>, (2015).
- Cotteleur, M., Mahto, M., Sniderman, B., *Industry 4.0 and manufacturing ecosystems*, [https://www2.deloitte.com/content/dam/insights/us/articles/manufacturing-ecosystems-exploring-world-connected-enterprises/DUP\\_2898\\_Industry4.0ManufacturingEcosystems.pdf](https://www2.deloitte.com/content/dam/insights/us/articles/manufacturing-ecosystems-exploring-world-connected-enterprises/DUP_2898_Industry4.0ManufacturingEcosystems.pdf), (2016).
- Czopik, G., Kraszewski, T., Technologia szerokopasmowa UWB w lokalizacji obiektów w pomieszczeniach zamkniętych, *Przegląd Elektrotechniczny*, No. 8, pp. 186-191, (2014).
- Davis, N., Schwab, K., *Shaping Fourth Industrial Revolution*, World Economic Forum, Cologny/Geneva, (2018).
- Deloitte, *The Fourth Industrial Revolution is here – are you ready?*, [https://www2.deloitte.com/content/dam/insights/us/articles/4364\\_Industry4-0\\_Are-you-ready/4364\\_Industry4-0\\_Are-you-ready\\_Report.pdf](https://www2.deloitte.com/content/dam/insights/us/articles/4364_Industry4-0_Are-you-ready/4364_Industry4-0_Are-you-ready_Report.pdf), (2018).
- Deloitte, *Industry 4.0: Challenges and solutions for the digital transformation and use of exponential technologies*, <https://www2.deloitte.com/content/dam/Deloitte/ch/Documents/manufacturing/ch-en-manufacturing-industry-4-0-24102014.pdf>, (2015).
- Deloitte, *Technology, Media and Telecommunications Predictions*, <https://www2.deloitte.com/content/dam/Deloitte/global/Documents/Technology-Media-Telecommunications/gx-deloitte-2017-tmt-predictions.pdf> (2017).
- Geissbauer, R., Schrauf, S., Vedsø, J., *A Strategist's Guide to Industry 4.0*, [https://www.strategy-business.com/article/A-Strategists-Guide-to-Industry-4.0?gko=7c4cf&utm\\_source=itw&utm\\_medium=20170302&utm\\_cam](https://www.strategy-business.com/article/A-Strategists-Guide-to-Industry-4.0?gko=7c4cf&utm_source=itw&utm_medium=20170302&utm_cam), (2016).
- Geissbauer, R., Schrauf S., Vedsø, J., *Industry 4.0.: Opportunities and challenges of the industrial internet*, <https://www.pwc.pl/pl/pdf/industry-4-0.pdf>, (2016a).
- Helbig, J., Kagermann, H. Wahlster, W., *Securing the future of German manufacturing industry: Recommendations for implementing the strategic initiative INDUSTRIE 4.0*, [http://www.acatech.de/fileadmin/user\\_upload/Baumstruktur\\_nach\\_Website/Acatech/root/de/Material\\_fuer\\_Sonderseiten/Industrie\\_4.0/Final\\_report\\_\\_Industrie\\_4.0\\_accessible.pdf](http://www.acatech.de/fileadmin/user_upload/Baumstruktur_nach_Website/Acatech/root/de/Material_fuer_Sonderseiten/Industrie_4.0/Final_report__Industrie_4.0_accessible.pdf), (2013).
- Łyda, K., Miłosz, M., Możliwości wykorzystania beaconów w reklamie, *Journal Computer Sciences Institute*, Vol. 4, pp. 76-81, (2017).
- Schwab, K., *The Fourth Industrial Revolution*, World Economic Forum, Cologny/Geneva, (2016).
- Stenzel, J., *Lean Accounting. Best Practices for Sustainable Integration*, John Wiley & Sons, Hoboken, New Jersey, (2007).

## Logistics parks – from theory to practice

Alexandru-Constantin Petrache<sup>a,\*</sup>

<sup>a</sup>*West University of Timisoara, Faculty of Economics and Business Administration, Timișoara, 300115, Romania*

---

### Abstract

Logistics is a complex science through which thousands of tons of freight are moved around the world each day. Logistics means not only planning but also execution. Day and night an army of workers, means of transportation, freight terminals assures that loads are going from point A to point B. Near every city around the world were developed logistics parks, storage spaces and freight terminals. Through the following paper an analysis of the literature about worldwide logistics is done, the situation of a European market leader in logistics is shown and also will be presented the current situation on the transportation and logistics market from a Romanian county.

*Keywords:* transportation; storage; logistics parks; freight

---

### 1. Introduction

All over the world, the freight volume and traffic increased significantly over the last decades. Logistics parks are now significant nodes of modern logistics systems (Dai & Yang, 2013). When we talk about logistics, nowadays we need to consider not only the means and ways of transportation; either we speak about road, rail, water or air transportation systems, but also about the handling, storage and forwarding of the freight.

All the cities are connected through highways, railroads, ports or airports. The developed cities understood the future in logistics and all major cities have now spaces where the freight carried with the train, can be offloaded and then loaded in trucks, or airplanes in order to arrive to the final destination.

### 2. Literature review

The early concepts about logistics (Neeraja, Mehta & Chandani, 2014) considered only the main activities such as transport and storage. But today is also about intermodality (Záhumenská & Gašparík, 2017), and the concept of quattro modal freight hub (Hauger, et al., 2016).

With the increase of the freight transportation volume, the Logistics Service Providers (LSPs) dimension and their behavior changed (Rolko & Friedrich, 2017), in order to offer integrated services for customers. It's not only about transporting freight from one point to another, but also offering the customer the best solution to his problem.

Today, a logistics park is a place with a variety of logistics facilities, warehouses and storage units near a highway, railroad, port or airport. A logistic park can be operated by a LSP, or the LSP rents a warehouse where he runs his activities.

The theory also presents the key performance indicators (Záhumenská & Gašparík, 2017) or the criteria and measures (Akdoğan & Durak, 2016) used in the evaluation of a logistics park, but in the end it's all about the size, the storage capacity, multimodality and the location (either if we talk about a city or a way of transport).

Today, more and more it's about finding new ways for an efficient and effective transportation operation. The hub-and-spoke model (Crainic & Kim, 2006) from an airport business model seems to fit well also in freight transportation on road, railroad or water. For a better logistics planning in transportation, the best way is to gather all the freight in one place, then to prepare load units that are going in the same direction. It's all about the costs and timing.

---

\* Corresponding author. Tel.: +40-746-121915  
E-mail address: alex.petrache15@gmail.com

### **3. European logistics leader**

According to a document released by the economic development agency of the Federal Republic of Germany (Friedrich & Pfeiffer, 2010), the German economy is the world's fourth largest after the United States, China and Japan. This thing happened because of the European Union's eastward expansion. With this expansion more goods pass through Germany now then through any other country in Europe. That led to a significant boost in Germany's logistics sector.

The main concern in Germany's logistics sector was the linkage between numerous ways and means of transportation. Storage facilities and multimodal terminals were built along the main highways in Germany, and also logistics hubs and facilities were developed near the big cities in every region.

Regarding the innovation performance, Germany is classified as an innovation leader, according to Innovation Union Scoreboard 2014 (Maticiuc, 2015), and in addition with the information already presented, we can deduct that these logistics hubs from Germany can be considered logistics clusters, "Innovative forms of spatial organization, in order to ensure a more efficient and effective business by using the synergy between organizations" (Maticiuc, 2014).

Between the characteristics of a successful logistics hub and also the main functions that this logistics hub should fulfil, we can mention:

- Customized solution,
- Handling, warehousing and transfer of goods,
- Access and proximity to the market,
- Strategic location,
- Multimodality,
- Intermodal terminals.

With some of Europe's most advanced transportation networks, well-trained workforce and also a stable political and economic environment, Germany can be considered the best possible base for European and global logistics operations (Rolko & Friedrich, 2017).

The logistics infrastructure in Germany is so well developed that near every city logistics operations run day and night. We can see a connexion between two or more ways of transport in order to obtain efficiency and effectiveness. Key players use or operate intermodal hubs in order to store, ship and manipulate the freight.

### **4. Timiș county logistics situation**

Timiș county, situated in west of Romania, with a population of more than 680000 inhabitants and a surface of 8700 km<sup>2</sup>, is the largest county in Romania in terms of land area and on the border with Hungary and Serbia (Consiliul Județean Timiș, 2018).

With a population of more than 330000 inhabitants and a surface of 130 km<sup>2</sup>, the city of Timișoara is an important economic, cultural and scientific center. Timișoara is an important commercial node, where many big companies from Europe and all around the world decided to invest here.

On the road, Timișoara is a node for important European and national roads. The Romanian Highway A1 passes NNE of the city, linking Timișoara with Hungarian Highway M43. On air, Timișoara is served by the third busiest airport from Romania, situated at about 12 km NE from the city center. On the railway, Timișoara has a direct link with Belgrade, Budapest and Vienna from the main railway station and also with the major cities from Romania (Primăria Timișoara, 2018).

The logistics market in Timișoara is quite developed from a storage facility point of view. In the last decade, around Timișoara were built true logistics parks.

- VGP Park Timișoara
- CTPark Timișoara
- Timișoara Airport Park
- Dunca Logistic Park
- Olympian Logistics Park

VGP Park Timișoara (VGP, 2018) is located 8 km ENE from the city center easily accessed from E70 and near "Traian Vuia" International Airport and has a built-up surface of approximately 70000 m<sup>2</sup> of warehouse, production and administrative space. This logistics park suits for production facilities and service companies, showrooms and headquarters, warehouse and logistics and it offers turnkey custom-made solutions.

CTPark Timișoara (CTP, 2018) is located 10 km E from the city center with fast access to the A1 Highway and close to "Traian Vuia" International Airport and has a total built-up area of 32000 m<sup>2</sup>, and also a planned construction of 61000 m<sup>2</sup>. This logistics park offers flexible, long term lease, proximity to highway and airport, turn-key, built to suit solutions to fit clients' requirements, flexible options for dock levelers and loading ramps.

Timișoara Airport Park (TAP1) (Invest4SEE, 2017) is located in the NE part of Timișoara between the city ring road and A1 Highway. TAP is a modern industrial park with over 102000 m<sup>2</sup> of industrial and logistics space.

Dunca Logistic Park (AIC Industrial & Logistic Development, 2018) is located in the N of Timișoara, between the city ring road and DJ691. This logistics park offers over 45000 m<sup>2</sup> of logistics spaces and around 8000 m<sup>2</sup> of offices.

Olympian Logistics Park (GVA Activ, 2018) is located 11 km E from the city center and has a direct access from E70 being also close to “Traian Vuia” International Airport. This park offers more than 27000 m<sup>2</sup> of warehouse space.

We can see that all major logistics park around Timișoara developed near the A1 Highway and the airport, mainly because in Romania most of the freight is shipped on the road despite the fact that since 2010 Timișoara city authorities are trying to build a Regional Intermodal Freight Center (Primăria Timișoara, Monitorul Primăriei Municipiului Timișoara, 2010), but with all the bureaucracy the project was put on hold. A lot of freight is also transported on the rail road, by the national railroad transporter (CFR) or private companies. But there is no intermodal hub to connect the road and railroad shipment.

All the major companies that rented spaces in the logistics parks around Timișoara use this space only to store their products in order to a further shipment to client. The main function of these logistics parks seems to be the storage, so from this point of view, if we speak about the logistics functions, the logistics market in Timișoara is not so well developed. We don't have LSPs who can offer a solution to companies. Either we speak about transport of freight, or storage, but there is no LSP to offer this combined service, and also the infrastructure is not developed to help LSPs to ship freight via railroad with lower costs, and only to or from client with trucks.

The main advantage of the logistics parks around Timișoara is the proximity of the A1 Highway. In this way, the city is connected with Europe, that's why a lot of companies decided to invest in Timișoara. Also DHL, a well known logistics company decided to invest in a small cargo terminal at “Traian Vuia” International Airport, because the airport infrastructure can allow here also cargo airplanes. This can represent a big plus for the logistics parks situated in the proximity of the airport.

## References

- AIC Industrial & Logistic Development, Industrial Real Estate Romania. Access on 20.08.2018 at <https://www.aicre.ro/delivered-projects/dunca-logistic-park-1>, (2018).
- Akdoğan, M. Ş., & Durak, A., Logistic and marketing performances of logistics companies: A comparison between Germany and Turkey, *12th International Strategic Management Conference, ISMC 2016, 28-30 October 2016, Antalya, Turkey, Procedia - Social and Behavioral Sciences*, Volume 235, 576 – 586, (2016).
- Consiliul Județean Timiș, Prezentarea județului. Access on 20.08.2018 at <http://www.cjtimis.ro/judetul-timis/prezentarea-judetului.html#main-menu>, (2018).
- Crainic, T. G. & Kim, K.H., Intermodal Transportation, *Transportation*, Volume 14, 467-537, (2006).
- CTP, CTPark Timișoara II. Access on 20.08.2018 at <https://www.ctp.eu/industrial-warehouse-office-finder/romania/ctpark-timisoara-ii/>, (2018).
- Dai, Q., & Yang, J., Input-output Analysis on the Contribution of Logistics Park Construction to Regional Economic Development, *13th COTA International Conference of Transportation Professionals (CICTP 2013), Procedia - Social and Behavioral Sciences* Volume 96, 599-608, (2013).
- Friedrich, J. D., & Pfeiffer, M., Germany: Europe's Logistics Hub, Berlin: Germany Trade and Invest Gesellschaft für Außenwirtschaft und Standortmarketing mbH, (2010).
- GVA Activ, Industrial spaces and warehouse logistics for rent. Access on 20.08.2018 at <https://www.proprietati-industriale.ro/en/properties/west/timisoara>, (2018).
- Hauger, G., Wanjek, M., Berkowitsch, C., Pfoser, S., Schauer, O., Putz, L.-M., et al., Concept of Quattro Modal Freight Hubs, *World Multidisciplinary Civil Engineering-Architecture-Urban Planning Symposium 2016, WMCAUS 2016, Procedia Engineering* Volume 161, 2121 – 2126, (2016).
- Invest4SEE, Real Estate Capability Statement. Access on 20.08.2018 at <http://www.google.ro/url?sa=t&rct=j&q=&esrc=s&source=web&cd=11&cad=rja&uact=8&ved=2ahUKewjJIM3Rs5TdAhUSKVAKHawcAQgQFjAKegQIBBAC&url=http%3A%2F%2Finvest4see.com%2Fwp-content%2Fuploads%2F2017%2F05%2Finvest4SEE-Real-Estate-Capability-Statement-April-2017.pdf>, (04 2017).
- Maticiu, M., Top-down and Bottom-up Cluster Initiatives in Europe, *Annals of the University of Petroșani, Economics*, Vol. 14(1), 205-212, (2014).
- Maticiu, M., The Complex Relation Between Clusters and Innovation In European Union, *ECOFORUM*, Volume 4, Issue 2 (7), 99-103, (2015).
- Neeraja, B., Mehta, M., & Chandani, A., Supply Chain and Logistics For The Present Day Business, *Symbiosis Institute of Management Studies Annual Research Conference (SIMSARC13), Procedia Economics and Finance*, Volume 11, 665 – 675, (2014).
- Primăria Timișoara, Monitorul Primăriei Municipiului Timișoara. Access on 20.08.2018 at [http://www.primariatm.ro/m/2-Monitorul\\_Primariei\\_Timisoara/10-Consiliul\\_Local\\_Timi%2F05%2F05%2Finvest4SEE-Real-Estate-Capability-Statement-April-2017.pdf](http://www.primariatm.ro/m/2-Monitorul_Primariei_Timisoara/10-Consiliul_Local_Timi%2F05%2F05%2Finvest4SEE-Real-Estate-Capability-Statement-April-2017.pdf), (16. 03 2010).
- Primăria Timișoara, Municipiul Timișoara. Access on 20.08.2018 at <https://www.primariatm.ro/>, (2018).

- Rolko, K., & Friedrich, H., Locations of Logistics Service Providers in Germany - The basis for a new freight transport generation model, *Transportation Research Procedia* Volume 25, 1061-1074, (2017).
- VGP, VGP Park Timișoara. Access on 20.08.2018 at <http://www.vgp.cz/en/industrial-parks/romania/vgp-park-timisoara>, (2018).
- Záhumenská, Z., & Gašparík, J., Supporting the connection the logistics centers to rail network. TRANSCOM 2017: International scientific conference on sustainable, modern and safe transport, *Procedia Engineering*, Volume 192, 976 – 981, (2017).

## Clusters – Value Added Creators for SMEs

Mădălina Dumitrița Maticiu\*

*Faculty of Economy and Business Administration, Pestalozzi Bd. 16, Timișoara 300115, România*

---

### Abstract

Clusters support the competitiveness of SMEs and they foster the growth of economies in transition and developing countries. They give enterprises the chance to gain experience and to improve the services they offer. Before forming strategic partnerships, SMEs should evaluate their capabilities and their potential, and should take into account the fact that, inside a cluster, SMEs can benefit from the synergy between members that fosters the individual competitiveness. The purpose of this paper is to review the existing literature on creating added value by clustering and to identify the main research tendencies in this area of interest. The study focuses on improving our understanding of the relation between value and capabilities in SMEs partnerships formation inside clusters.

*Keywords:* cluster, Small and Medium Enterprise (SME), added value, competitiveness, innovation

---

### 1. Introduction

Competition between firms has become more and more fierce in recent years following the globalization process. As a result, SMEs have encountered several opportunities but also threats. Opportunities aim at creating multiple chances to increase individual competitiveness by going through a process of change (Mariana Predișcan (2001) argues that „... organizational change is an action, a set of actions, a process that aims to change, partial or total transformation of an organization, of its component elements or of the processes taking place here, allowing the transition from the present state to a desired future state, which differs quantitatively and / or qualitatively from the first. The objective of organizational change is to establish a new state, instead of the existing one”) and the threats are created by the small size of SMEs, reminders that can bring remarkable competitive advantages if SMEs are to cooperate with other private and public representatives to achieve the synergy effect. In this regard, clusters have been created in many countries of the world to support SMEs in gaining competitive advantage by disseminating various resources (human, material, informational).

### 2. Challenges for SMEs

SMEs (Small and medium-sized enterprises) are defined by OECD in 2000 as „non-subsidiary, independent firms which employ fewer than a given number of employees. This number varies across national statistical systems. The most frequent upper limit is 250 employees, as in the European Union. However, some countries set the limit at 200 employees, while the United States considers SMEs to include firms with fewer than 500 employees. Small firms are generally those with fewer than 50 employees, while micro-enterprises have at most ten, or in some cases five, workers. Financial assets are also used to define SMEs. In the European Union, SMEs must have an annual turnover of EUR 40 million or less and/or a balance-sheet valuation not exceeding EUR 27 million.” (OECD, 2000).

SMEs are very specialized in their specific activities. „This increases the importance of effective interaction with other firms and public research institutions for R & D, exchange of knowledge and potential for commercialization and marketing activities.” (Tal A., 2017)

---

\* Mădălina Dumitrița Maticiu Tel.: 0040256592563 ; fax: +40-(0)256-592500.  
E-mail address: madalina.maticiu@e-uvt.ro.



The current business environment in which SMEs operate is characterized mainly by a strong competition, both at national and at international level. „SMEs have gradually become the "engine" of the national economy and human resources occupy a vital position in developing activities.” (Demyen S., 2012)

The European Union aims, based on the Europe 2020 strategy and through policies and programs to support SMEs to create an attractive environment for their emergence and development so that the EU economy becomes „the most competitive and dynamic knowledge-based economy in the world”. As Günter Verheugen, European Commissioner for Industry and Entrepreneurship, said: „ Europe's entire force is involved in supporting SMEs by involving all Europe's resources to support small businesses in their day-to-day work and to pave the way for those who want to create more jobs and develop in Europe and not only.”

Competitiveness is a more and more used concept by economists, which involves the ability to increase market share, profit and value added (Ramasamy, 1995). The low competitiveness in some of the Eastern European countries can be explained by the many problems they face. Much of the products made in these countries are sold at very low prices, and they often resort to intermediate distribution channels, and these markets are rich in imported products. Even the labor force problem is not to be neglected, much of the population in these states is paid with low wages, which is why a part of the population reaches work in more developed countries. People are active in various fields of activity, being one of the basic resources of companies. The quality of human capital is generally the result of population education and qualification. The abilities of individuals are sometimes limited due to the lack of knowledge and education. In SMEs, there is often a tendency to engage family members, relatives, friends and acquaintances, although they lack the necessary knowledge for the posts they occupy. Although there are many cases where such companies have not been successful, there is the opposite side, where SMEs have been family-owned businesses passed on from generation to generation and have retained their success over time. Outside the big urban centers in developing countries, the issue of the labor force itself, and not its quality, is a real obstacle. Labor migration is a real phenomenon in some countries, and this is a real problem for SMEs too.

To preserve the competitive advantage, SMEs must cope with competition, not only in terms of quality and price for the services or products offered but from the point of view of knowledge and technology. This has gone from pursuing a traditional competitive advantage to a modern one, creativity and innovation. Competitiveness and implicitly economic growth have as main factor innovation, and this is not only specific to developed countries but has spread throughout the world economy. Including the OECD recognizes that "innovation (...) is faster and more intense, more closely related to scientific research" (OECD, 2000). Creativity has become an entrepreneurial performance, the strategic approach being focused on identifying resources, capabilities, skills and opportunities. In order for the SME sector to create greater added value in the economy, SMEs are committed to becoming more innovative by creating products with increased added value. Clusters can help SMEs by taking over production and the marketing of these products on a much larger scale, but all of this through the efforts of SMEs to develop their entrepreneurial skills.

### **3. Gaining added value with clusters**

According to Michael Porter, clusters „are new forms of organization (...) that offer advantages in terms of efficiency, effectiveness and flexibility.” He was the first person who offers the first most complex definition of the cluster as „ geographic concentrations of interconnected companies and institutions in a particular field. Clusters encompass an array of linked industries and other entities important to competition. They include, for example, suppliers of specialized inputs such as components, machinery, and services, and providers of specialized infrastructure. Clusters also often extend downstream to channels and customers and laterally to manufacturers of complementary products and to companies in industries related by skills, technologies, or common inputs. Finally, many clusters include governmental and other institutions--such as universities, standards-setting agencies, think tanks, vocational training providers, and trade associations.” (Porter, 1998).

A cluster is a form of innovation in organizing the business space with the potential to add more value than companies adopt a simple collaboration relationship. One of the central processes of adding value within the cluster is the transfer of knowledge. The main purpose of cluster policies in all countries is to increase the level of innovation, R & D and to achieve the clustering benefits of SMEs, start-ups, improved efficiency and added value (EU Best Practice in Cluster Development Policies, 2012).

Separating the cluster term from innovation is difficult to achieve. Innovation comes inside the cluster as a way of expressing an unprecedented experience that can create the network effect in terms of creating added value. Within the cluster, innovative ideas are supported through cooperation and collaboration, often cooperative to create new value for all stakeholder categories. Innovation can often suffer some bottlenecks mainly because of the costs and accumulated knowledge. Developing countries often face problems such as: the promotion of guarantee instruments is often inadequate, the profit obtained is insufficient to guarantee bank loans and the high innovation cost. Also, within the cluster appears the exemplification of the concept of co-innovation that has become increasingly important in clusters, especially in the context of a very competitive market like the current one. As more and more people use social technologies to get what they want from other people, rather than through formal channels, such arrangements are missing among the less experienced people. Co-innovation is a platform where new ideas or approaches from different

internal or external sources are applied differently to create new value or experience for all stakeholder categories, including for consumers. The core of co-innovation includes commitment, experience and co-creation of value that is difficult to imitate by competition. The co-innovation platform is built on principles of idea convergence, collaboration agreement and co-creation of stakeholder experience (Lee, S.M., Olson, D. L., Trimi, S., 2012). Organizations find it difficult to survive for a long time if they pursue their own interest, not emphasizing shared value with stakeholders. In this context, we can talk about the commitment of all members, the acquired experience, innovative ideas, and of course the collaboration agreement between the cluster members.

SMEs involved in clustering must make real and useful decisions, considering the widespread availability of competitive and opportunistic information, the development of technologies and the speed of change that is the same for all competitors. To do this, businesses must have well-defined skills to identify, select, collect and process data and information, and transform them into knowledgeable decision-making. Companies also should have a tremendous anticipation capability in the complex and turbulent environment in which they work, proactivity being a challenge not only at the organizational and regional level but also globally.

One of the early forms of a cluster was the industrial cluster as a group of enterprises and non-profit organizations for which cluster membership is an important element of the individual competitiveness of each member firm.

Buyer-supplier relationships within the industrial cluster have led to the formation of the concept of a cluster based on the value chain. A cluster based on the value chain is an industrial cluster identified as an extensive chain of entry-exit or buyer-supplier. This includes final market producers and three levels of suppliers that engage directly and indirectly in trade, consisting of several sectors or industries (Roelandt, den Hertog, 1999). A cluster of the value chain is in line with an industrial cluster as defined by Czamanski and Ablas: "A subset of the industries of the economy linked to stronger flows of goods and services than their association with other sectors of the economy

national "(Czamanski, Ablas, 1979). It can also be defined as a potential where businesses can or cannot carry out commercial activities among themselves, but they may eventually take place in the future.

Where entrepreneurial culture is not well outlined, there is a low interest in innovative activities, research and development and partnership. At European Union level, it is trying to support scientific research and the implementation of results that have not been applied before, encouraging performance. Nadvi and Barrientos 2004, considered clusters as a tool for poverty reduction, especially in extra-urban areas where the informal economy predominates and where SMEs predominantly employ unskilled workers. In their conception clusters are dynamic and engage in increasing the degree of innovation of their products, in switching to activities and functions with higher added value and in disseminating the accumulated experience to increase the competitive advantage. „Fostering public-private partnerships and small-firm networks and clusters may be the most expeditious path to a dynamic SME sector... Clustering facilitates the exchange of personnel and diffusion of technology and creates new possibilities for efficiency gains.” (OECD,2000).

Surely the decision to be part of a cluster is not easy to take. SMEs typically use local resources, have developed a certain attachment to their local business partners. To join a cluster, SMEs can decide pooling resources acquired selectively or wholly, for example only a part of the value chain or the entire chain of the whole company. Depending on the size of the SME, they can contribute to cluster both with activities with high added value (such as research, development, design, after-sales service) and with those that have an added value lower in the value chain (such as manufacturing, processing and basic services). One of the benefits of belonging to a cluster is that low value-added activities are not outsourced to emerging economies and those with high value to more advanced economies. The small size of SMEs requires material profits not so substantial that does not allow them to create an experience of lending needed to develop, investments do not amount to sufficient values to improve existing technologies (often wear and tear and obsolescence) and not infrequently due a poor business culture is geared towards creating value-added products or services with little added value.

Once part of a cluster, SMEs benefit from a set of advantages given by what a large company is, namely everything that was considered a disadvantage due to the small size of SMEs is now becoming an asset because it is a part of a large company, and besides, it will not have to remove the two main advantages of a small company, namely specialization and flexibility. According to Schmitz and Nadvi in 1999 „clustering helps firms to ‘overcome growth constraints and compete in distant markets’”.

In its Communication COM (2008) 652 "Towards the setting up of the world level in the European Union - implementation of a comprehensive innovation strategy " the aim of EU is to support the development of clusters as a strategic priority for sustainable economic growth. The communication referred to several ways to promote clusters in the European Union by creating new policies and continuous improvement of existing ones, promoting national and international cooperation within the clusters and by fostering the integration of many small and innovative media in clusters. Through the same document, the European Commission is committed to supporting Member States in formulating clustering policies, ensuring communication infrastructure at European level, supporting cluster integration of innovative SMEs but calls on Member States to adapt national policies to European ones , to support the involvement of SMEs in clusters in line with the recommendations of "smart specialization" and to engage in ensuring synergies and complementarities between clustering policies.

#### **4. Conclusions**

Clusters are constantly looking for durable solutions for their businesses, interactions that go beyond the cluster value chain become evident. Of course, the specialization of a company in a particular branch may cause the need to identify another within or even outside the cluster if the entire economic agglomeration is focused on a single industry if the market requires integrated products and services. The ability of companies within a cluster to cooperate with the outside grows as there is easy access for outsiders to engage in cluster activities. Including public authorities, special attention has been paid to this type of cooperation not only at the national and European level. Collaboration between cluster members allows them to make innovations that would have been individually difficult to build. Thanks to the collaboration and physical and communication proximity between cluster members, it is much easier for them to do incorporate downstream or upstream knowledge into the value chain and thus bring competitive advantage within the cluster. The main advantage of innovation co-operation is given at cluster level precisely by the relations between the members, not only cooperating and in a competitive relationship, the desire to overcome the rivals' performances giving rise to cooperative innovation.

#### **References**

- Czamanski, L. A., Ablas, Q. Identification of Industrial Clusters and Complexes: A Comparison of Methods and Findings. *Urban Studies*, 61-80, (1979).
- Demyen, S., The impact of the Brain Train phenomenon on the human resource management in Romanian SMEs, *The Annals of the Economic Faculty*, Volume 2, Editura Eftimie Murgu, Reșița, (2012).
- La Porta, R., Lopez-de-Silanes, F., & Shleifer, A., Corporate ownership around the world. *Journal of Finance*, 54(2): 471-517. (1999).
- Lee, S.M., Olson, D. L., Trimi, S., Co-innovation: convergenomics, collaboration, and co-creation for organizational values", *Management Decision*, Vol. 50 Iss: 5 pp. 817 – 83, (2012).
- Nadvi, K., & Barrientos, S., Industrial clusters and poverty alleviation: Mapping links and developing a methodology for poverty and social impact assessment of cluster development initiatives. Working Paper. United Nations Industrial Development Organization, Vienna, (2004).
- OECD, Small and Medium-sized Enterprises: Local Strength, Global Reach. OECD policy brief, (2000).
- Predișcan, M., Managerizarea schimbărilor organizaționale, Timișoara, Editura Mirton, (2001).
- Ramasamy, H., Productivity in the age of competitiveness: Focus on manufacturing in Singapore. In *Productivity in the Age of Competitiveness*, APO Monograph Series (16), Asian Productivity Organizations, Tokyo, (1995).
- Porter, M., Clusters and the New Economics of Competition Documentation. Harvard Business Review, Boston, (1998).
- Roelandt, T., den Hertog, P., Cluster analysis and cluster-based policy making in OECD-countries. OECD, (1999).
- Schmitz, H. and Nadvi, K., Clustering and industrialization: introduction. *World Development*, 29, 1885-1903, (1999).
- Tal, A., Social Media Platforms and Romanian SMEs. An Innovation Perspective. *Annals of the „Constantin Brâncuși” University of Târgu Jiu, Economy Series*, Issue 3/2017, (2017).
- \*\*\* European Commission, Comunicarea Comisiei Europene Către înființarea de grupuri de nivel mondial în Uniunea Europeană: implementarea unei strategii ample privind inovarea. Bruxelles: COM (2008) 652, (2008).
- \*\*\* EU Best Practice in Cluster Development Policies (2012). Maxwell Stamp PLC accesed at: <https://poduzetnistvo.gov.hr/UserDocsImages/EU%20projekti/IPA%20IIIC/Podr%C5%A1ka%20razvoju%20klastera/5.Izvje%C5%A1taj%20o%20najboljoj%20praksi%20u%20EU.pdf>

## Analysis of companies' behavior in smoothing conflicts of interest

Tatiana Dănescu<sup>a</sup>, Maria Alexandra Botoș<sup>b</sup> \*

<sup>a</sup>Universitatea Petru Maior Târgu Mureș, România

<sup>b</sup>Universitatea 1 Decembrie 1918 Alba Iulia, România

---

### Abstract

Within corporations and large entities, some internal policies and practices are typically designed and regulated to prevent and resolve conflicts of interest. Multinational entities, especially those listed on the stock exchange market, elaborate codes of ethics or internal standards that guide all persons who have contact with the entity, including collaborators. Through this paper, we aim to identify the behaviour of the above-mentioned entities on an international level, regarding the conflict of interest and its risks.

The results presented are based on a quantitative and qualitative analysis of a sample of 177 multinational entities around the world. In order to achieve the purpose of this research, we took into account over 321 guides, manuals, standards and conflicts of interest policies that were made public by the entities in the selected sample.

**Keywords:** Conflict of interests; Risk management; Management; Companies' Behavior; Code of Ethics.

---

### 1. Introduction

The phrase conflict of interest is associated in particular with terms such as fraud or tax evasion, but according to some opinion it can only evolve in fraud and tax evasion if the conflict of interest is not effectively managed. However, non-identification and recognition of conflicts of interest may lead to risks that are closely linked to the reputation of the entity and the loss of public confidence; moreover, a decision based on a conflict of interest is in most cases vulnerable and can be challenged in judgment. However, it is worth mentioning that there are situations in which allowing the manifestation of conflict of interest brings a benefit to the entity, over the scenario in which it would have been prevented.

Thompson D.F. (2009) argues that the emergence of conflict of interest is due to a set of circumstances that are responsible for creating a substantial risk that the professional judgment of a person of primary interest is influenced by a secondary interest. This definition is included in the Report on Conflict of Interest developed by the United Kingdom Audit Office and is in line with international audit standards. The Romanian legislation defines conflict of interest as the situation or circumstance in which the direct or indirect personal interest of a contracted person is contrary to the public interest in such a way that it affects or might affect its independence and impartiality in taking decisions or objectively fulfilling the duties of the person.

Therefore, we consider the conflict of interest to be classified according to the entities affected by its manifestation in: Conflict of interests on the public environment and conflict of interest on the entity's internal environment. We define the first type of conflict of interest as the accumulation of intrinsic and extrinsic conditions that trigger an action to obtain a benefit, which is in detriment of a third parties' interest, anyone except the employing entity. The second type, the conflict of interest regarding the interest of the employing entity, we consider to be the accumulation of the intrinsic and extrinsic conditions that lead to the manifestation of an action for the purpose of obtaining a personal or professional benefit, which can affect positively or negatively the employing entity.

---

\* Corresponding author. Tel.: +40 756 587 381; fax: +40 265 233 389.  
E-mail address: botos.alxandra@yahoo.com.

## 2. Research methodology

The process underlying this research is primarily aimed at identifying the risks posed by the conflict-of-interest behaviour of multinational organizations. The approaches that we have taken to achieve this results are: fundamental research, based on the theoretical documentation and critical analysis, carried out with the help of the professional experience and the previously accumulated knowledge from the field of ethics of behaviour and internal control; comparative research, between international frameworks in which conflict of interest is manifested; causal research based on qualitative analysis of multinational practices and policies; empirical research based on a combination of quantitative and qualitative analysis of the predetermined sample set for research.

The first stage of the research aimed specifically at identifying the practices and policies of entities, on conflict of interest, at an international level. The proposed objective was achieved through the process of documentation and comparative analysis of the existing framework at national, European and global level. The second stage aimed at presenting organizational practices and policies on conflict of interest resolution and prevention. This objective was achieved through the analysis of the information resulting from the documentation process.

Finally, the third stage aimed specifically at identifying practices and policies to smooth the conflicts of interest used by multinational organizations. The empirical study, that stood at the foundation of our efforts to identify practices and policies to mitigate conflicts of interest used by multinational organizations, was achieved through the quantitative and qualitative analysis of 177 entities selected from the 540 multinational list of Forbes International, the main selection criteria being financial indices: turnover, profits and total assets, and the disclosure of their conflict of interest policies on the public domain, such as government sites or sites of the entities being analyse.

## 3. Practices and policies regarding the conflict of public interest

From our professional experience, we have noticed two situations in which the conflict of interests is strongly associated with the decision-making process, namely: in the case of affiliated transactions and in the case of shareholder loans. Therefore, we have resorted to analyzing these two situations at an international level to observe the level of risk it presents. We consider relevant the comparative analysis of the legal framework in which the conflict of interest is present in the case of transactions between related parties, especially at an international level. In order to carry out this analysis, I proceeded to the elaboration of Table 1.

Table 1. Comparative analysis of the conflict of interest framework for affiliate transactions

	National setting	Other European countries	Other countries in the world
	Market Value and Price transfer Principles		
Legislative framework	In Romania, in commercial or financial transactions between affiliated parties, if the nature or characteristic of the transactions made, differ from those that would have occurred with another independent entity, any amount of profit that would have been realized by one party may be included in the profit tax base. According to the legislation, Romanian Law 207/2015, it is necessary to carry out the price transfer dossier, which is used as evidence for the tax authorities.	At European level in June 2006, the European Council adopted the Code of Conduct on Price Transfer. Entities in the Member States are obliged to apply both the code and the national legislation. There are also avoiding double-taxation regulations such as Directive 2011/96 / EU on the common tax regime applicable to mother companies and their subsidiaries in different Member States.	At international level, the Organization for Economic Cooperation and Development has contributed to the international harmonization process by providing a Guide for Price Transfer for Multinational Enterprises and Tax Administrations updated in 2017.
	At present, in Romania, the legislator encourages the creation of groups of companies, but profit tax determination is not acceptable based on tax consolidation system. This gives the group the opportunity to manipulate financial results within the group through transactions and transfers.	Fiscal consolidation In 2011, the European Commission drew up a proposal to implement a consolidated tax base, by this proposing a single set of rules for the whole Europe. The proposal was re-launched in 2016 but was not approved by the European Council.	In the USA and Canada there is a form of fiscal consolidation called formal distribution. Formal distribution is a method of allocating the profits of an entity or a group to a particular tax jurisdiction in which the entity is taxable, and by this there rest of the entities of the group are not taxed separately.

Source: Made by the authors based on information from the documentation process

The structure of the table being focused on two broad concepts that we have found as international practices and which, according to our professional experience and literature, are strongly correlated with the conflict of interest in the case of transactions between affiliated parties, namely: the principle of market value and price transfer and the consolidated tax base.

According to a theory developed by Hyde and Choe (2005) in practice, two types of price transfers are used: the taxable price transfer, used to obtain the most favorable tax result and the incentive price transfer, used to provide appropriate incentives for off-shore assets. As can be seen in Table 1., at international level, many steps have been taken to reduce the risk of conflicts of interest. Currently, we have identified two situations of affiliated parties' loans that are related to the conflict of interest and are being conducted at an international level, addressed in Table 2, namely: shareholders crediting the entity or shareholders loan and the entity loaning to the directors.

Table 2. Comparative analysis of the legal framework for the related parties' loan

	At an national level	At an European level	Worldwide
		Shareholders Loan	
		Loaning to the administrator or directors	
Legislative framework	In Romania according to the present legislation, shareholders and associates are allowed to credit the entity by charging related interest with restrictions only in the case of cash payments, in which case the legislation permits transactions amounting to a maximum of 10,000 RON (national currency) between individuals and commercial entities in the case of loan.	There are no directives at EU level with precise specifications in this regard. Rules similar to those in Romania are also found in France. Meanwhile other states are legislating this case in the code of insolvency, for example England and Germany, where an associate loan is only accepted as to save the entity from bankruptcy.	In China, the loaning of the entity is often seen by tax authorities as a capital contribution which is not recoverable so fast as a firm loan, in order for it to be qualified as a loan, the entity has to provide a mortgage to the shareholder to secure the loan.
	Currently, the Romanian legislation, Law 31/90, only regulates the administrator's loan by the entity. Under the law, loans to the administrator are forbidden unless their due amount is less than € 5,000 and if the lending terms are not different from the terms of credit to others or are not an exception to the entity's current activity.	There are no directives at EU level on this issue. In England, loans may be granted to directors with the approval of the General Assembly. In Denmark, credits to directors or associates are recognized as wage entitlements or dividends and taxes are charged correspondingly.	In the US, granting a loan to one of the shareholders is permitted provided that the interest rate is above the monthly rate set by the federation. If the interest is below the required level, the loan is given the name of "below market level loan" and becomes taxable. A similar approach is also found in South Africa, where loans that have interest below market level or other suspicious circumstances are considered to be dividends or wage entitlements and are taxes are charged.

Source: Made by the authors based on information from the documentation process

In Romania, the legal framework is more permissive in terms of loaning the entity and lending to its directors than to other countries in Europe or the world. In Romania it has become a trend for the money invested in the establishment of an entity to be considered credit provided by the associate and to be subsequently recovered as to cover absence of money from the treasury. In the literature, we have noticed this inclination to address only the situation of a shareholder loan if the entity is in a poor financial state or in the event of bankruptcy.

The scientific literature presents methods of identifying conflicts of interest relevant especially to the person who is the subject of this phenomenon. As follows a series of manuals and guides have been produced, but such techniques are also used to make codes of ethics of multinational entities for employees and management, this being more or less detailed. The general consideration is that under certain circumstances the act of declaring the potential or actual conflict is sufficient to adequately mitigate or manage the conflict of interest. According to a manual made by the Institute of Medicine there are two models of conflict of interest management, namely: the prohibition model, which specifically defines conflict of interest rules and the consequences of their violation; the model of disclosure and evaluation, which is taking into account guidelines mentioned in the previous paragraph.

Due to this we considered it relevant to classify the conflict of interest according to the related risks, stating that the number of risks is not limited to those mentioned in this classification:

- Financial conflict of interests: refers to the risk of financial loss that the entity may suffer, it can be more easily identified in comparison to the other categories, but the underlying reasons may not be the most influential;

- Professional Conflict of interests: refers to the risk that the trust and image of the entity in the collaborators and clients view may suffer;
- Informational Conflict of Interest: refers to the risk of loss of informational confidentiality.

#### 4. Case study on the domestic practices and procedures of multinationals

In order to have a clearer picture of what the international conflict resolution behavior means and how it is manifesting, we appealed to the analysis of a sample of 177 global entities, chosen on the basis of three financial criteria; turnover, registered profit and total assets and the condition to have disclose public codes and policies on conflicting interests. The distribution of the sample by geographical area can be seen in Figure 1.

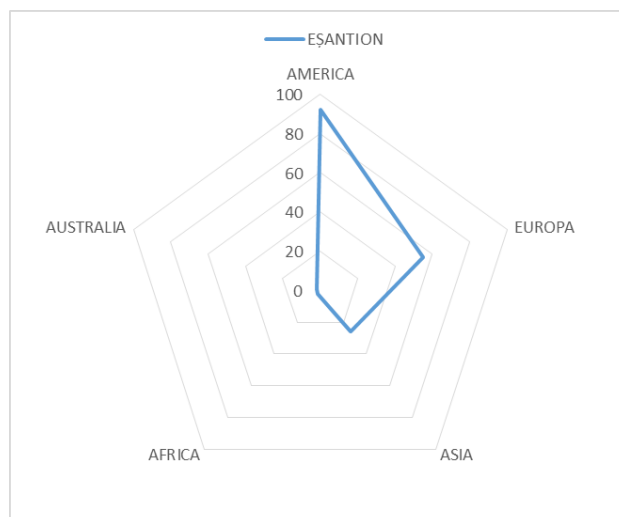


Figure 1 Batch distribution based on geographic areas

The first step in analyzing the sample was to identify subjects who published relevant conflict of interest information and whether they were updated over the past two years. Note that for the purpose of data processing, we used the IBM SPSS Statistics 25 program, and the Cronbach Alpha coefficient was equal to 2.88, certifying the consistency of the sample as an excellent one. We also mention that each subject of the sample has in some cases presented multiple manuals and guides on conflicts of interest practices and procedures, each of which is intended for a different category: employees, management, board of directors and collaborators. The analysis was extended to all identified conflicts of interest information, with a total of 321 manuals, policies and guides analyzed.

A second step in our research has been to identify the type of conflict management model used by each subject and whether there is a correlation between it and the staff responsible for conflict resolution and management of conflicts of interest. The analysis resulted, according to Table 3 processed by the SPSS Statistics 25 program, that 47.5% use the prohibition model by clearly specifying what is allowed and what is not allowed, in some cases with the indication that any employee who is unable to decide whether or not he is in a conflict of interest situation to address his superior or a named person. The 51.4% left use the disclosure model, referred to in the manuals sometimes as Whistleblower policy, in which case concrete examples of potential conflicts of interest are shown, so that the employees will understand what it signifies and so that they are motivated at any time if they realize that they are in a conflict of interests situation or are in uncertainty that they are, to address the person responsible.

Table 3. Analysis of the sample composition according to the management model

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	,00	2	1,1	1,1	1,1
	1,00	84	47,5	47,5	48,6
	2,00	91	51,4	51,4	100,0
	Total	177	100,0	100,0	

Source: Generated by the SPSS Statistics Program 25

In the research, we found that some of the subjects created special compartments for the management of compliance of employee behavior with the code of ethics, some assigning this task to management, and others did not mentioning who is responsible for this task. Therefore, we considered the SPSS verification of the correlation between the model used and the existence of a special compartment dedicated to the compliance of the employees' behavior with the code of ethics. According to Table 4, as can be seen, the bivariate correlation is 0.37 greater than the recommended limit of 0.01, therefore it is significant. We find that subjects using the prohibition model tend not to mention who is responsible



for the task of managing employee behavior compliance with the code of ethics, and those using the disclosure model assign this responsibility to management and the Compliance Bureau at an equal level.

Table 4. Bivariate correlation between the model used and the department responsible for managing the behaviour of employees in the code of ethics

		Model used	Responsible
VAR00009	Pearson Correlation	1	,372**
	Sig. (2-tailed)		,000
	N	177	177
VAR00008	Pearson Correlation	,372**	1
	Sig. (2-tailed)	,000	
	N	177	177

\*\* . Correlation is significant at the 0.01 level (2-tailed).

In addition to the quantitative analysis, we present the following practices identified in conflict of interest codes and practices that have been noted and considered relevant to the study:

- Some codes specifically mention the fact that it is forbidden to grant loans to employees and executives employed, to avoid conflicts of interest;
- A significant number of entities state in the Code that if conflict of interest cannot be avoided, it should be treated fairly while others state that in some cases, if possible, the person concerned will be required to cancel or remedy some actions;
- Certain entities such as Bank Rakyat, British American Tobacco and Brookfields are annually requesting their employees' reports on the conflict of interest from the previous year;
- Citic Securities mentions the use of the Chinese wall method to prevent conflict of interest, which is to restrict the flow of information from one department to another, in particular due to the financial and confidential quality of the information. Restrictions including physical (geographic location) and digital restrictions, employees are not allowed to communicate by e-mail.
- Dai-ichi Life have created special roles for monitoring conflict of interests, they are called group monitors, and the person who is in this role has an obligation to report any apparent or possible conflict of interest;
- Some entities such as Boeing have presented questionnaires by completing of which employees can see whether they are or not in a conflict of interests;

Following the qualitative analysis of the above mentioned codes, manuals and procedures, we identified the following risks, which are advisable to be considered in the future:

- Risk of non-identification:
  - Considering the Chinese wall model used by some companies, we express a reservation on the guaranteed functionality of the conflict of interest method, and we want to emphasize that the isolation of departments can lead to a difficult identification of conflicts of interest by the management or department responsible;
  - Most entities rely totally or to a certain extent on self-identification and self-declaration in the event of a conflict of interests by employees, in our opinion this method is not guaranteed and needs a solution to complement it.
- Risk of noncompliance:
  - Considering that employees complete some questionnaires and reports at the end of the year, the risk that they are not in line with reality is very high due to the lack of a verification and control system;
  - Also, due to the limitation of this study, we emphasize the possibility that the practices and procedures elaborated in ethics codes and guides may not be implemented in the entities is very high, due to the fact that there is no evidence of this process.
- Conflict risk:
  - Because of the Whistleblower policy, there are risks of creating conflicts between employees. Considering that each of them has to declare apparent conflicts of interest, without the need for evidence to underpin their claims;
- Risk of no conformation:
  - By observing the prohibition model in ethical codes, we have identified a very harsh and rigid language and that it contains all the interdictions that employees have in their personal lives and the consequences that they might suffer in violation of these regulations. We believe that such an approach is inefficient especially for young and non-conforming employees.

## **5. Conclusions**

We conclude that there is currently no certainty that existing practices ensure transparency and disclosure of conflicts of interest. Consequently, the entities behavior of conflict resolution is difficult to track and test, but from the analysis we identified the following types of risks that arise from current practices:

- According to the analysis of scientific literature: financial risk, professional risk, risk of confidentiality of information
- According to the analysis of the study sample: the risk of non-identification, the risk of noncompliance, the risk of conflict and the risk of no conformation.

However, we would like to mention that this list is limited to the sample studied and the information obtained from the analysis process and we do not consider that the risks of conflict of interest are limited to it. In addition to this study, in the future we take in consideration to conduct an analysis of the situation of entities in Romania and their behavior regarding the management and resolution of the conflict of interest.

## **References**

- Di Carlo E., Testarmata S., Recognizing and Managing Conflicts of Interest: the Case of Italian Listed Companies, Essays in Management, Economics and Ethics, vol 20, pp 3-24, (2012).
- Hilscher J., Şişli- Ciamarra E., Conflicts of interest on corporate boards: The effect of creditor- directors on acquisitions, Journal of Corporate Finance, Vol 19, Pages 140-158, (2013).
- Institutul de Medicină, Patient Outcomes Research Teams (PORTS) Managing Conflict of Interest, The National Academies Press, pp. 61-68, (1991)
- Proposal for a COUNCIL DIRECTIVE on a Common Consolidated Corporate Tax Base (CCCTB) - <http://www.consilium.europa.eu/>
- Richards H., What Is a Shareholder Loan?, (2017), preluat de pe - <https://bizfluent.com/>
- Thompson, D.F., The challenge of conflict of interest in medicine, German Journal for Evidence and Quality in Health Care, vol. 103, n. 3, pp. 136-140, (2009).
- Vutt A., Subordination of Shareholder Loans in Estonian Law, Juridica International, Vol XV, pp. 86-93, (2008).
- Legea 31/1990 art. 144(4) privind Interzicerea creditării administratorilor de către societate
- Legea 207/2015 art. 4 alin. 2 privind operațiunile de încasări și plăți în numerar Organizația pentru Cooperare și Dezvoltare Economică, Ghidul privind prețurile de transfer pentru întreprinderile multinaționale și administrațiile fiscale, (2017) preluat de pe - <http://www.oecd.org/>
- The World's Largest Public Companies List, (2018) - <https://www.forbes.com>
- UK National Audit Office, Conflicts of interest, (2014), preluat de pe <https://www.nao.org.uk>

# Analysis of managers' behavior in Industrial Companies in the North West Region

Alina Natalia Pop\*, Gabriel Rus

*Technical University of Cluj-Napoca, Faculty of Engineering and Management Romania,*

---

## Abstract

Managerial analysis is an important element in the development process of any organization, bringing to the fore the human resource and the results obtained by it.

The behavior of each manager depends on three characteristics that are determined by heredity, education, and mentality. Managers need to adapt their behavior to the group or team of employees they lead in industrial firms to create a pleasant and effective workplace atmosphere, and it is necessary to adhere to certain rules of behavior towards subordinates.

Managerial behaviors analyze leadership styles, differentiated by human resource categories, into authoritarian, democratic and laissez-fair styles. One of the characteristics of efficient managers is their flexibility, due to the continuous flow of major changes in industrial firms and technologies.

The behavior of the manager can often be influenced by his membership of a particular organization. Some organizations have rules so strict that the manager can not put into practice his own leadership style. In this situation, personal preferences are not taken into account, only what the organization considers to be fair behavior is accepted.

The rich and continuous data flow of information that is absolutely necessary for decisions is inconceivable in conducting activities in an industrial firm as well as solving problems. Managerial behavior means knowledge, experience, data and ideas about business opportunities.

Keywords: consumer, competitiveness, the human resource, industrial firms

---

## 1. Introduction

Man's ability to know is inseparable from his ability to evaluate, making selection and systematization of information possible. Whether it targets goals, phenomena or processes, placing a certain scale on a certain position usually determines attitudes, decisions and actions.

This spirit of innovation and entrepreneurial spirit, driven with integrity, devotion and ethics, was part of the vision of management within industrial firms.

Industrial firms are distinguished by ethical relationships within existing networks, being a strong feature distinguishing themselves from other companies.

Industrial firms believe that their results are incontestable due to their basic rules, of which the most important is ethics. Doing business properly is the motto of industrial firms, and each employee, managerial, has the responsibility to read and understand the principles of the Code of Ethics: law enforcement, integrity of registration and reporting of financial results, proper maintenance, accurate and complete records financial compliance, respect for human rights, quality delivery through quality services and products, ethical competition - competitive advantage through superior performance, respect for diversity and fair employment practices, avoiding conflicts of interest - avoiding relationships or behavior that could compromise judgment create apparent or real conflicts between personal interests and loyalty within them, protecting goods and information, confidentiality of information and data about employees, integrity,

---

\* Corresponding author. Tel.: +0-744-369-718;  
E-mail address: alinanataliapop@gmail.com.

compliance with laws, rules and special regulations that relate to government contracts and relationships with government personnel, the environment, health and safety becoming global leaders in defending the health and safety of our employees and protecting the environment.

## 2. Problem Statement

The assessment of the managerial activity results within the industrial firms, the objectives and the relations developed, is a condition of managerial adaptation. The evaluation allows for the correct identification of the deficiencies and the means that led to their realization, as well as the possibility of improvement of each evaluated person. The performance appraisal system must always be linked to the company's specificity as well as to other human resources policies. It will not be considered as an activity in itself, but should be related to the identity of the industrial firms of certain organizational aspects: structure; values; benefits of evaluation, organizational development measures; training system, development of career plans; promotion and relegation system, etc. (Pânișoară, 2017).

Most of the time, when we think about the role and impact of evaluating managers' performance on the other components of human resources management that they are developing, we ask ourselves the following questions: How should I make the assessment?; Where should I start?; Where do I need to go?.

In order to get answers to these questions, it will start from Ralph W. Tyler's analysis, which involves highlighting an axis that has the conception of activity at one end, and at the other end the objectives of the industrial firms.

From this point of view, we notice that in practice we will meet five types of balance between the goals of the firms and the results obtained by the manager.

The ideal model, results and goals are equal, the companies has proposed something, and the manager has achieved the following goals:

- a) The ratio in which the objectives of the industrial firms are much higher than the employee's possibilities.
- b) Report against the previous situation.
- c) Intersection model - when the employee achieves only some of the objectives required by the cluster, but there are goals obtained outside the employer's requirements.
- d) The least desirable case - the ratio of the industrial firms' objectives and the employee's results are zero. (Pânișoară, 2017).

In order to make these equilibrium patterns easier to remember, they are shown in figure 1:



Fig. 1. The five types of balance between the objectives of the industrial firms and / or the department and the results of the employee (Pânișoară, 2017).

Feedback can be considered as having only an evaluation purpose of the performance of individual attitudes and behaviors, but can also serve as a way of streamlining communication within the organization (setting goals, feedback, drawing up the action plan, implementing the action plan, evaluating results) (Bocean, 2015)

## 3. Research Questions/Aims of the research

The notion of personality is all-encompassing, referring to the individual's behavior and how this behavior is organized and coordinated in the interaction with the environment.

The personality of the manager is involved in all the hypotheses and roles within the industrial firms. It gradually builds, over time, effective practice with a particularly important role in shaping and finalizing it.

There are two categories of requirements requested by the manager:

- 1) Personality requirements: Constitution and temperament of the subject; Physical environment; Social environment; Habits and skills gained under the influence of previous influences.
- 2) Requirements relating to intellectual qualities: Intelligence; Ability to recognize; Ability to accept and apply the new one; The ability to think clearly; Memory; Imagination; Predictability; Practical thinking; Theoretical thought. (Gabriela and Cibela, 2009).

The performance of industrial firms is the result of mobilizing the resources they have.

The characteristics of this assessment that distinguish it from the rest of the traditional assessments are:

- Operates with a set of evaluation samples.
- It can only be made by people or firms specializing in this.
- Assumes collaboration between the employee and the evaluator.
- The evaluation activity has a permanent carcass.
- Ensures interaction with the outside environment by reporting employees' performance to those profile firms.

Position analysis in a small and medium-sized enterprises appears in four assessment situations:

- 1) When defining the need for personnel of industrial firms.
- 2) For promotion policy within industrial firms.
- 3) When preparing the training plans.
- 4) To re-establish the salary scale. (Dorel U, 2001)

These principles are the directions of action to be followed throughout the performance management process, defined as follows:

- 1) Excellency of services - each employee must contribute to the improvement of services and to the satisfaction of internal and external customers by identifying their needs.
- 2) Improving the quality and safety of work - each employee must be based on maintaining his / her activities of quality and security.
- 3) Support and development - each employee must have the resources to meet his / her goals within the industrial firms, be provided with the necessary assistance and support to continuously improve the results.
- 4) Responsibility - Every employee must use the resources he / she has in an efficient and timely manner.
- 5) Involvement - Every employee must continue to achieve the organization's goal. (Bocean, 2015)

Performance evaluation is two ways:

1. Non-formal evaluation: whether or not it is necessary, the daily relationship between the manager and the employee.
2. Systematic evaluation: it is required to take place at certain intervals, once or twice a year. This type of assessment involves direct contact between the manager, eventually assisted by a human resources and employee, the recording of impressions and remarks on the performance of employees is done in writing. (Liviu G. and Maria G, 2004)

#### 4. Research Methods

The APEX evaluation, reward and motivation model can be highlighted in Figure 2:

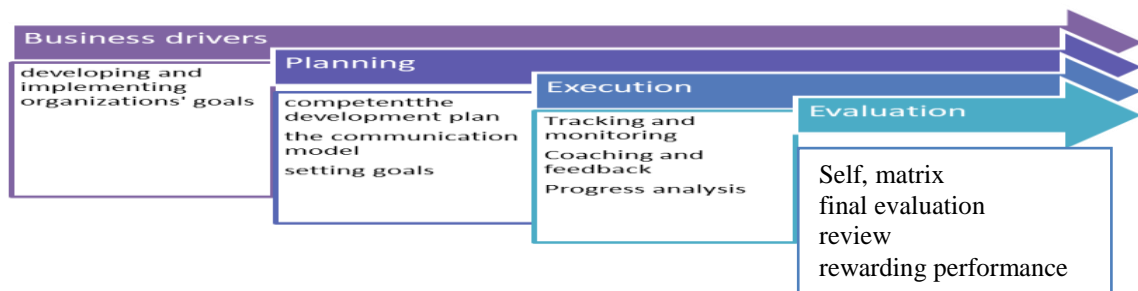


Fig. 2 APEX process; Source: own processing APEX

Coaching and continuous feedback

Business initiators: Planning - Execution - Evaluation - Excellent performance; Developing and evolving, organizational goals are the initiators of the business

Planning: November – January 1. Goal Setting 2. Competencies 3. Development Plan 4. Assessing the Leadership  
Execution: Throughout the year 1. Evolution and progress monitoring 2. Coaching and feedback 3. Verification of progress at the semester (June / July)

Evaluation - November - January 1. Own evaluation 2. Matrix and introduction of level 2 managers, 3. Final evaluation, 4. Evaluation session 5. Performance reward.

By using the APEX program, managers and employees plan and manage their performance so that they can achieve excellent performance from "do my job". Performance management and success in industrial firms.

Apex will help us: To be more valued on the market. This vision is determined by:

- What customers say: We want to do more business with this company
- What the shareholders say: This company is one of my best investments.
- What the employees say: I am proud to be part of this team.

Companies select the best and take responsibility for the quality of everything they do. Removes all barriers to achieve goals, to accomplish them quickly and efficiently, without compromising quality: Health and Safety; Excellency; Involvement; Communication; Remuneration; Study, Responsibility; Innovation; Commitment.

The basic steps for evaluating APEX include:

- Setting and tracking objectives;
- Choosing the necessary skills;
- Creation of the development plan;
- Granting and accepting coaching & feedback;
- Completion of performance assessments.

## Evaluation results Apex MFG 2017

- Approximately 1250 direct and indirect employees (SCMs) were assigned and evaluated (including calibrated).
- Most supervisors have subordinated dozens of employees who received the objectives, were evaluated, calibrated, completed the evaluation sheet, brought to the knowledge, provided the copy of the card.
- Distribution of quotations received after the evaluation was:
- The quotations received after the evaluation was:

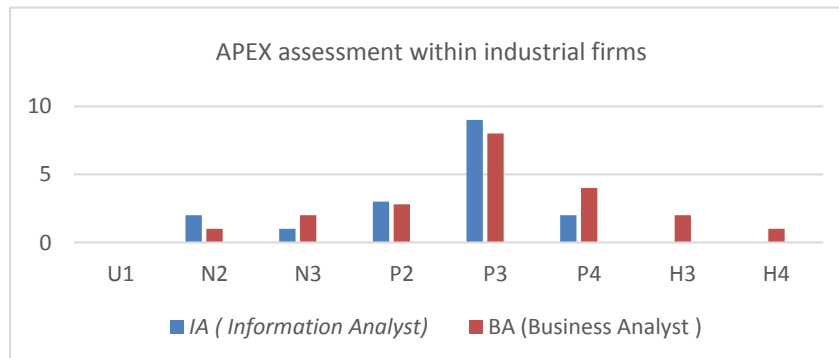


Fig. 3 Apex MFG 2017 rating; Source: own processing

## Categories of objectives offered

- Health and safety (wearing protective equipment all the time and reporting at least a near miss or observation)
- Quality (constructive participation in maintaining the rebuttal in the set target)
- Productivity (compliance, achievement of the individual efficiency indicator)
- Lean (respecting and supporting Lean tools applicable to the workplace - SW, TPM, improvement ideas)
- Customer Satisfaction (Ensuring good production flow, timely and correct materials preparation for internal and external customers to reduce the number)

## Requested skills:

- Professional knowledge (knows the process and working well, does not require guidance, can work on several phases of work)
- Involvement-orientation on individual and team goals (most often agree with overtime and change of work)
- Labor discipline (complies with the rules, does not have disciplinary sanctions)
- Communication and teamwork (communicates well with positive relationships with others, helps when needed)
- Learning and development (maybe and wants to learn, ask questions, make an effort to learn)

## Improvements to the process:

- Introduction of the Lean objective.
- Closer (individual) expression of objectives.
- Reforming skills descriptions to allow employees who know how to work on multiple work phases.
- Provide a copy of the 2017 Employee Assessment.
- Delivering goals to indirect workers from production

## Findings:

- Offering new employees' goals, returning or changing jobs and joining another type of employee - within 30 days of hiring.
- Enhance the familiarization of employees with the objectives and skills required, their reminders at any occasion, given explanations and examples.
- Encourage employees to report near miss misses and ideas for improvement.
- Establish measurable indicators for assessing objectives and competencies.

Employees are assessed through APEX, the formal process of process performance management that supports the growth and progress of society by setting measurable goals, honest discussions and performance feedback. This annual process consists of ongoing performance feedback and performance coaching as well as a half-year performance discussion in the form of an assessment of progress and an end-of-year evaluation. APEX users are rated with a double performance rating, consisting of an alphabetical score for results and a numerical assessment for the leadership and demonstration of functional competence.

Evaluating the performance of the companies managers is done according to the APEX process. Managing individual performance is important for corporate success and is practiced by everyone starting from the general manager to the last worker. Performance means both things, namely, how and how everything is done.

Responsibility implies acceptance of objectives that are challenging as well as open and constructive feedback.

- Whoever needs development, anyone!

Developing is not just the problem of those experiencing difficulties in achieving performance or those who want to promote in leadership positions.

Creating an annual development plan helps to focus on study and continuous performance improvement.

- APEX manager tasks
- Set cascade goals for everyone in the team.
- Explain what is expected from employees, emphasize the goals to be developed.
- Ensure coaching and continuous feedback.
- Identify remarkable contributions.
- Ensure that you have development plans that meet the highest level of satisfaction, contribution and give the team added value.
- Ensure at the end of the year a comprehensive assessment and performance appraisal that will be discussed with employees at a meeting.
- Finalize on time through the APEX process.

APEX means achieving the goal, performance and excellence.

By using the APEX program, managers plan and manage their performance so they can get excellent performance from "do my job".

Basic steps include: Fixing and tracking goals; Choosing the necessary skills; Create your development plan; Granting and accepting coaching & feedback; Finalizing performance appraisals.

Objective: The results for which they are responsible: They are measured and evaluated at the end of the year; It helps to distinguish between good performance, a good one or a higher one.

Task: An activity that is required to achieve a goal; It is just "a way to end," not a plus of value in itself; It has no unit of measure; It is not included in the on-line personal evaluation form; Task setting in APEX is optional.

Measure: What measures or checks will be undertaken to ensure that the target has been successfully achieved. They can be both quantitative and qualitative.

Scope: Fix monthly, quarterly, or half-timer interim endorsements to help track the progress of a measure; Goal setting in APEX is optional; Competencies define the "how" of performance

#### A. Assessment of attributed competencies

Employee individual competencies are important for the successful completion of any activity carried out in industrial firms.

Competencies of senior management are important for successful completion of any management activity in industrial firms and will be automatically selected for managers and managers who have at least one employee subordinate. Competencies include the four dimensions of the leadership model:

1. (Linke Dreiecksseite) Think & Act Strategically - Business Spirit; Vision and goal; Intellectual rigor.
2. (Rechte Dreiecksseite) Get Results - Successful Skills; Change and adaptability; Effective use of resources.
3. (Dreiecksbasis) Structuring the organizational capacity - Managerial Courage; Responsibility; Developing and motivating staff.
4. (Rechteck unter dem Dreieck) Demonstrates leadership skills - Talent in interpersonal communication; Professional estate.

#### B. Apex Evaluation Process

- Achievements: Excellent; Extremely powerful; Performance; Requires improvement; Unsatisfactory.
- Conduct: 5 excellent skills - good model to follow; 4 very competent; 3 understands expectations; 2 proof of unconsciousness; 1 low –problematic.

#### C. Matrix of double evaluation

O1	O2	O3	O4	O5
H1	H2	H3	H4	H5
P1	P2	P3	P4	P5
N1	N2	N3	N4	N5
U1	U2	U3	U4	U5

Fig. 4. Matrix of double evaluation; Source: industrial firms

O - Outstanding - Excellent Achievement of Service Obligations. Achievements and Outstanding Achievement Outcomes.

H - Highly Effective- Extremely efficient in performing service tasks. Taking into account the degree of difficulty of the objectives, the available resources and the changes made during the year, had an irreproachable conduct.

P - Performance - Good performance in fulfilling the responsibilities of the service to find ways to 'overcome standards' of their own performance (on in-service training) and taking into account the difficulty of the proposed objectives, the available resources and the changes that occurred during the year, achieving the objectives were particularly satisfactory.

N - Need Improvement - Needs improvement with regard to continuous service tasks and / or needs for improvement and achievement of objectives. She can be responsible, but she needs to come up with more initiative and find a way to continually improve. It could be improved through coaching, feedback and a refinement plan.



U - Unsatisfactory- Unsatisfactory - it has shortcomings in terms of performing the service tasks and / or obtaining results. It is strict, requires a long-term improvement.

## 5. Conclusions

Within industrial firms it can be noted that the level and training of human resources is very important for a good day-to-day process. Their assessment of both employment and well-defined time is essential. Emphasis is placed on both the professional qualities and the character of the staff, trying to create a favorable climate, considering that, in a pleasant environment, favorable results are increasing.

The evaluation method used is Apex. This was chosen due to the potential of establishing the evaluation criteria.

The study highlighted the fact that a function should be evaluated in its entire complexity, each feature being extremely important for a company to function properly in terms of its structure.

Motivation and attitude towards work is of individual importance, reflecting his attitude towards work, but also at a collective level, which must be an example in this respect.

In conclusion, the method and way of assessing human resources in industrial firms are chosen in order to facilitate the execution and management processes, following the personal and professional development of their employees, in order to benefit from the highest level of performance.

The goal of performance management within Romanian industrial firms is to achieve better results for the organization by improving individual performance.

Performance appraisal within industrial firms is one of the most important parts of performance management.

The performance appraisal system must always be linked to the company's specificity as well as to other human resources policies. Managing individual performance is important for the success of industrial firms and is practiced by everyone starting from the general manager to the last worker.

Proposals:

Introducing a feed-back questionnaire on employee expectations related to the work of general manager and management team, if they are in the company's new philosophy, if they think they are heading for a good direction.

## References

- Andrew D., *Personnel and Human Resource Management* , Van Nostrand eds., London, (1981)  
Bocean C. G, *Managementul Resurselor Umane*, Universitaria eds., Craiova, 90-101, (2015)  
Cucos C., *Managemen* , Editura Polirom, Iași (2002)  
Dorel U., *Managementul Resurselor Umane*, Colecția Universitaria esd., 126-128, (2001)  
Gabriela M. și Cibela N., *Fundamente ale psihologiei manageriale*, Tritonic eds., Oradea, 70-82, (2009)  
Georgeta Pânișoară și Ion O., *Pânișoară Managementul Resurselor Umane*, Polirom eds., Iași, 139-146, (2017)  
James M., *Management*, Tenth Edition eds., Munchen, (2004)  
Liviu G. și Maria G., *Managementul Resurselor Umane*, 2004, Casei Corpului Didactic eds., Baia Mare, 208-216, (2004)  
Mihuț I., *Management General*, Carpaticea eds., Cluj-Napoca, (1993)  
Russu C., *Management strategic*, Expert eds., București, (1993)

## Utilization of “Value Analysis” in determination of competitiveness level with in S.C. EUROSPORT DHS SA

Guță Anca Jarmila \*

*\*University of Petroșani, Petroșani, 332041, Romania*

---

### Abstract

The value analysis is a method of competitiveness wich aims at increase of products value by a systematic procedure with the object of obtaining optimum solution. The paper proposes to present, using the value analysis with in the company S.C. EUROSPORT DHS SA, on the basis of a questionnaire the degree of satistaction of the customers concerning the products of the company taken for object of research.

*Keywords:* company, customers, value analysis, competitiveness level, degree of satisfaction, products range, EUROSPORT DHS

---

### 1. Introduction

The value analysis is:

- An organized and creative competitiveness method aimed at meeting the needs of the user through a specific, functional, economic and pluridisciplinary approach (French NF X 50-150)
- Method of conception or reconciliation of products and services to meet the user's needs at a reasonable cost.
- Organized procedure to identify unnecessary costs (L. D. Miles).
- Organized procedure for identifying unnecessary costs in multi-component products, using Functional Analysis to define the problem and group creativity to solve it (W. L. Gage).
- Method of increasing the material production by reducing manufacturing costs, while improving the quality of products, acting at the stage of constructive design (P. Orănescu).
- Method of conducting material production.
- A series of system processes geared to delivering the necessary functions at a minimal cost, without neglecting quality, reliability and delivery.
- A method for increasing the value of both products and services or technological processes, by means of which a systemic procedure tends to obtain optimal solutions.
- Research method - systemic and creative design which, through a functional approach, seeks to ensure that the functions of the studied objective are conceived and achieved with minimal expenses, in a quality condition that satisfies the needs of the users, in accordance with the socio-economic requirements.

**The objectives of the Value Analysis are:** cost reduction, quality improvement and required services, innovation, conquering new markets, adapting to external developments, ensuring sustainable competitiveness. The Value Analysis object forms its activity, product or components. Only the product is a value carrier and the subassemblies or parts contribute to the usefulness of the product.

**The Value Analysis Directorate is Functional Analysis.** Starting from the idea that a product is bought because it does something that corresponds to a buyer's need, this property has been named its principal function. In order for the main function to be fulfilled, a series of secondary functions need to be added to the product, which is of interest only if it contributes to the normal function of the main function. It is estimated that, in general, only 20% of the manufacturing costs of products are caused by the main functions, and 80% of the secondary functions.

---

\* Corresponding author

E-mail address: gancajarmila@yahoo.com.

## 2. Presentation of the company subject to the study

A Chinese math teacher, Yang Xi, left her native country in 1996 with her husband, Niu Guanghui, to start a business in Romania. They chose Petrosani, where they built the foundations of a bicycle factory in 1999.

The choice of location was based on two reasons: unemployment in the Jiu Valley, which guaranteed its availability on the labor market, and the second fact that at that time the Jiu Valley benefited from the status of the disadvantaged area. Ten years later, Yang Xi succeeded in inaugurating a second bicycle factory in Deva. The bicycle factory is located near the town of Deva, the central-western part of the country and is the country's largest bicycle manufacturing facility. Eurosport DHS is China's largest investment in Romania. Up to now, around 20 million euros have been invested here.

PROPHETE GMBH, Germany's number two bicycle manufacturer in Germany, bought 30 percent of EUROSPORT DHS shares with capital and at the same time gained 100 years of experience in Germany. In 2006 EUROSPORT DHS invested in the new production plant in Deva, more than 6 million EURO and with a production area of more than 17,000 square meters. In June 2006, Prophete GmbH entered into a partnership with Eurosport DHS SA bringing in this partnership both the capital and 100 years of experience in the production of bicycles at German standards. In July 2006, the massive investment of approximately 300,000 Euros in an automatic technological line for the assembly and centering of bicycle wheels (6 wheel adjustment equipment purchased from the French manufacturer Mach1, a company specializing in the production of bicycle wheel construction equipment .), and by acquiring automated assembly lines in the Netherlands that guarantee the quality of products as European standards, the company's production has grown to 500,000 units per year.

This investment was made taking into account the opportunity for bicycle production in Romania. The bikes produced here are sold throughout the European market since January 2007 when Romania became a member of the European Union. Eurosport products have some very important features: good quality and low prices thanks to the low cost of local labor.

The wide range of products and services, together with the long-established professionalism and reliability, have put Eurosport DHS S.A. among the first companies in the country. To prove this, the company holds numerous diplomas and awards. The National Council of Private Small and Medium Enterprises ranked Eurosport DHS S.A. for the third consecutive year in the first place in the category "Bicycle production".

In 2009, Chinese managers began building a new production hall, in which they invested another 2 million euros.

## 3. Determining the level of market competitiveness of S.C. EUROSPORT DHS SA

*The proposed questionnaire is the following:*

Company Name: \_\_\_\_\_

Date: \_\_\_\_\_

Your Name. \_\_\_\_\_

Your function . \_\_\_\_\_

### Customer Satisfaction Assessment Questionnaire

#### 1. What is the most important reason for working with Eurosport DHS?

- |                   |            |
|-------------------|------------|
| a) Seriousness    | d) Rate    |
| b) Promptness     | e) Quality |
| c) Product design |            |

#### 2. How do you qualify your relationship with the sales department?

- |              |           |
|--------------|-----------|
| a) Very good | c) Normal |
| b) Good      | d) Weak   |

#### 3. Is the best way to promote DHS products?

- |            |           |
|------------|-----------|
| a) Banner  | d) Media  |
| b) Poster  | e) Flyers |
| c) Catalog |           |

#### 4. Are your preferences about the 2017 product range?

- |             |             |
|-------------|-------------|
| a) Impulse  | d) DHS Kids |
| b) DHS      | e) Kreativ  |
| c) Trekking |             |

#### 5. The most sold product in the 2017 season was?

#### 6. Was the 2017 service activity?

- |              |           |
|--------------|-----------|
| a) Very good | c) Normal |
| b) Good      | d) Poor   |

#### 7. Is your opinion about Bike Fest 2017?

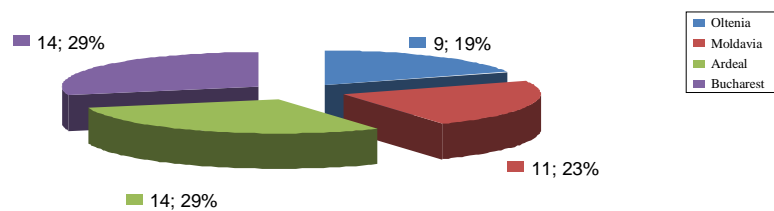
- |              |           |
|--------------|-----------|
| a) Very good | c) Normal |
| b) Good      | d) Poor   |

### Interpretation of results:

1) **What is the most important reason for working with Eurosport DHS?** This question seeks to determine the factor that most influences the collaboration with SC Eurosport DHS SA. This is a closed question with five variants of answer, of which the respondent chooses one.

In the following graph are presented the results of the analysis of the data obtained by this question. It is noted that most respondents, ie 58% of the respondents, consider seriousness as the most important factor that may influence the collaboration with Eurosport DHS, half of them, that is, 14, are from Bucharest and the rest of Transylvania. Only 19% of the respondents from Oltenia and 23% of Moldova consider the company's seriousness as the most important factor influence.

**What is the most important reason that influences the work with Eurosport DHS?**

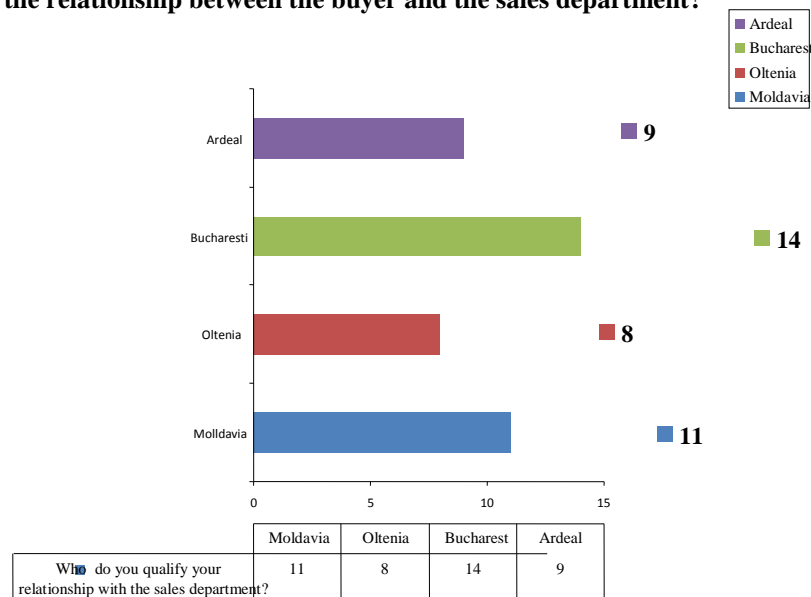


Scheme 1 - "Rated Deriousness"

2)

**How do you qualify your relationship with the sales department?** This question seeks to establish the type of relationship between buyers and the sales department. That question is closed, metric scale type

**The type of the relationship between the buyer and the sales department?**



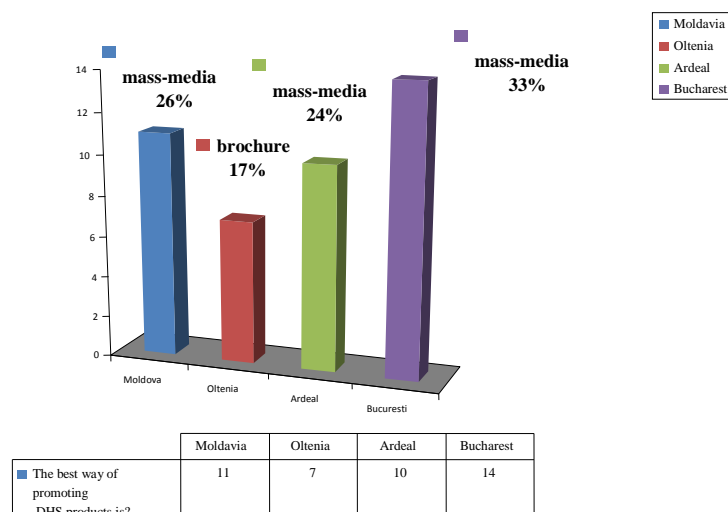
Graph 2- Rated "Very good"

From the above figure we can see that the area where most of the respondents qualified the relation with the sales department as being very good is Bucharest with 34% (14 persons), followed by Moldova with 26% (11 persons). Only 9 respondents from Ardeal consider that their relationship with the sales department of the company is very good (ie 21%), and in the Oltenia area, 19% of the respondents gave the same answer regarding their relationship with the sales department of the firm.

### 3) Is the best way to promote DHS products?

The role of this question is to determine the best way for the respondents to react and stimulate them to buy or at least to visit the Eurosport DHS store. This is a closed question with 5 variants of respondents that respondents can choose one.

### The way of promoting DHS products

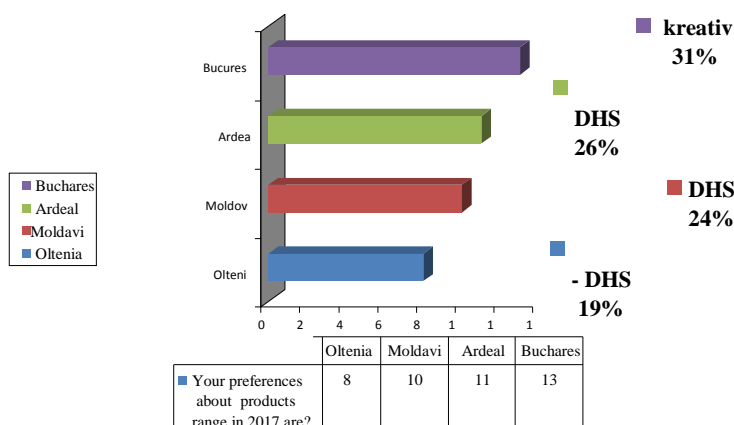


From the graph above, it can be seen that 33% of respondents in the Bucharest area, namely 14 persons, consider that the best way to promote DHS products is mass-media. In addition, the Moldovan and Ardeal regions are added with a 50% cumulative share (11 persons surveyed from Moldova and 10 from Ardeal), who opt for the same promotion of products as those in Bucharest. 17% of respondents in Oltenia state that the best way to promote DHS products is the catalog (7 people).

#### 4) Are your preferences about the 2017 range of products?

The role of this question is to determine the preferred product from 2017. It is a closed question with five variants of answer, of which the respondent chose one.

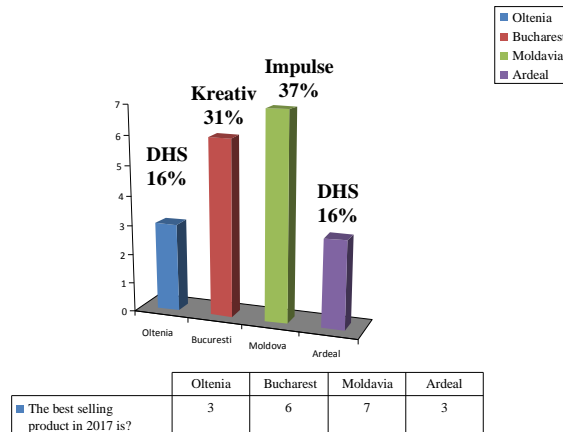
### 2017 preferred products by the buyer ?



From this chart it can be deduced that the preferred product of the buyer in 2017 is DHS, accounting for 69% (11 persons from Ardeal, 10 from Moldova and 8 from Oltenia respectively) compared to Kreativ that was voted by 31% (ie 13 persons) of respondents in the Bucharest area.

#### 5) The best-selling product of the 2017 season is?

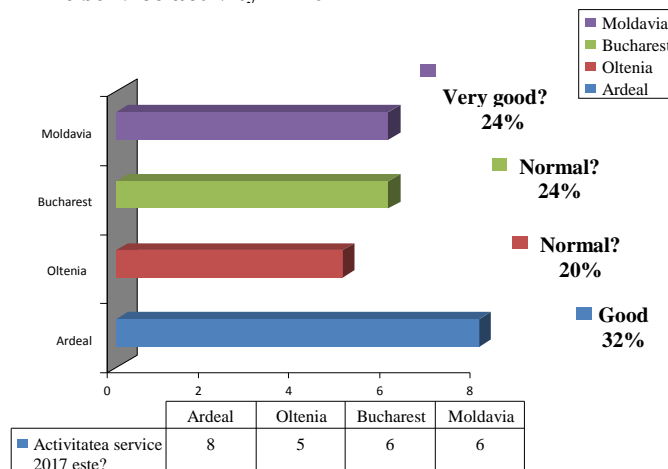
The role of this question is to determine the best-selling product of 2017. It is an open question for the respondent to write which is the product that had the highest earnings in the year 2017.

**The best selling product**

The graph above shows that the best selling product in the area of Moldova is Impulse with a weight of 37%, followed by DHS with a cumulated weight of 32% in the Oltenia and Ardeal areas. 6 of the people surveyed liked Kreativ as the best-selling product in 2017 in the Bucharest area.

**6) Is the 2017 service activity?**

This question is aimed at identifying how the service activity was qualified in 2017. It is a closed question with four variants of answer from which the respondent can choose one.

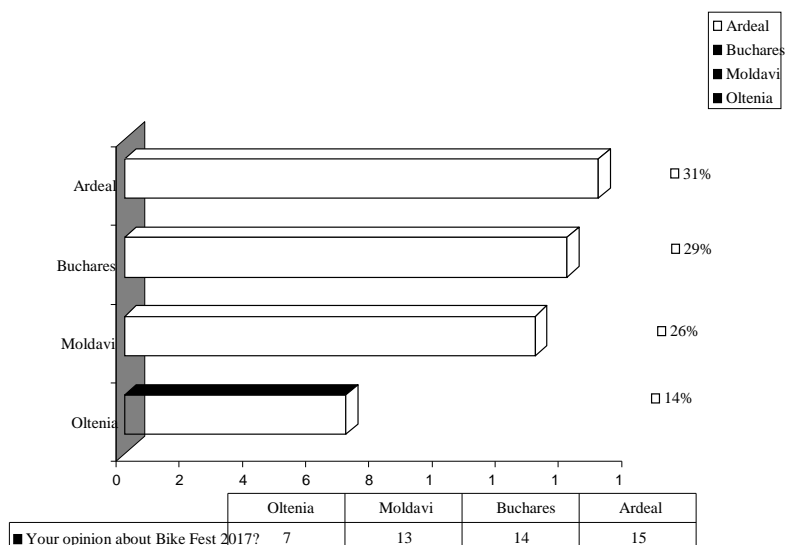
**The service activity in 2017**

From the above graph we can see that 24% of the persons surveyed in the area of Moldova consider the service activity from 2017 to be very good, unlike the Bucharest and Oltenia areas which claim that the service activity was normal in 2017, thus registering a weight of 24% (6 of the persons surveyed), respectively 20% (5 persons). Transylvania registered 32%, ie 8 people claiming Eurosport DHS's 2017 service was good.

**7) Is your opinion about the Bike Fest 2017?**

This question seeks to determine customer opinion on Bike Fest 2017. It is a closed question with four variants of the answer that the respondent chooses one, ending the collaboration with it.

### Bike Fest 2017



#### Quoted "Very Good"

From the above graph it can be concluded that among the people surveyed the most, who had a very good opinion about Bike Fest 2017, are from Ardeal, with a share of 31% (15 persons respectively). București registered a 29%, that is, 14 people interviewed, in this area is the Bike Fest of 2017 was a success with a very good opinion. Of the respondents in the Republic of Moldova, only 13 have this opinion (26%) and Oltenia, 14% meaning 7 persons.

### 3. Conclusions

The reaction of the customers entering the store, the ease with which the company's website can be accessed, or the way the seller comes to the customers are things that, although seem insignificant, make a vital contribution to the future of any business.

Adequate feedback is also a motivating force for employees, which strengthens self-confidence, commitment to the organization, and increases professional satisfaction.

The customer can choose from a wide range of products or may propose their own models to be produced at the factory in Deva. In the latter case, the customer benefits from the exclusivity of the models he has created. The company is very competitive in terms of prices due to the low cost of labor in Romania.

DHS has not only limited to bicycle production, but has continued to produce bicycle components, such as aluminum rims and body painting.

DHS directors contribute to "locating" EUROSPORT DHS products, meaning maximizing the use of components produced here. DHS acquired Italian painting equipment for the cadres, including this process in processes in Romania. This reduces the volume of imports but creates new jobs.

### References

- Bizerea M. *Marketing Business to Business*, Editura Mirton, (2006)
- Guță A.J., *Previziune și planificare strategică în afaceri și în instituțiile publice*, Editura Universitas, Petroșani, (2012)
- Guță A. J., *The role and importance of the business plan in starting and running a business opportunity*, publicată în Annals of the University of Petroșani, Economics, vol.14(2), (2014)
- Guță, A.J., MoneaM., Slusariuc G.C., *Particularities of budgeting of investments yield*, publicată în Annals of the University of Petroșani, Economics, vol.XI (2), (2011)
- Kotler Ph., - *Managementul Marketingului*, Editura Teora, (1997)
- Kotler Ph., *Marketing Management*, 7<sup>th</sup> edition, Editura Printice Hall, (1992)
- Verhoncu I., Nicolescu O., *Management*, Editura Economică, (1999)

\*\*\* - [www.dhsbike.ro](http://www.dhsbike.ro).



# The Moderating Role of Malaysian Government in Microcredit organization and Quality of Women Self-Sustainability

Waseem-Ul-Hameed<sup>a</sup>, Muhammad Imran<sup>b</sup>, Beata Ślusarczyk<sup>c\*</sup>, Adnan ul Haque<sup>d</sup>

<sup>a</sup>*School of Economics, Finance & Banking, Universiti Utara Malaysia, Malaysia*

<sup>b</sup>*School of Business Management, Universiti Utara Malaysia, Malaysia*

<sup>c</sup>*The Management Faculty, Czestochowa University of Technology, Poland and Faculty of Economic Sciences and IT, North-West University, Vaal Triangle Campus, South Africa*

<sup>d</sup>*Business and Management, University of Wales Trinity Saint David, London, United Kingdom*

---

## Abstract

This study is mainly based on the question; does Malaysian government support enhances the quality and positive contribution of Amanah Ikhtiar Malaysia (AIM) on the women self-sustainability? Thus, article attempts to examine the moderating role of governmental support regarding the effect of AIM on quality women self-sustainability. Therefore, using survey questionnaire data only collected from three hundred and eighty (380) female clients of AIM in Kedah and Perlis. Results confirmed that AIM has vital contribution while government support plays significant moderating role in increasing women self-sustainability in selected regions. Therefore, government support is major contributors toward quality of women self-sustainability among the female clients.

*Keywords: Amanah Ikhtiar Malaysia (AIM); Government Support; Microfinance; Small Loan; Women Self-sustainability*

---

## 1. Introduction

Women self-sustainability is known as the process of equipping women to be economically independent, self-reliant, having positive esteem which allows them to defend any challenging circumstances and contribute to various development activities (Kapila *et al.*, 2016). Women are the integral part of every society as women has major influence on economy (Ekpe *et al.*, 2010). However, cultural issue, beliefs and gender discrimination decreases the women sustainability level. This gender discrimination is still existing in Malaysia. In various sectors of Malaysia still inequality exists between men and women. For instance, at managers position men earns RM5080 (=€1075) and women earns RM4500 (=€952). Moreover, in craft and related trade men earns RM1330 (=€281) and women earns RM879 (=€185), and so on in all various fields (Department of statistics, 2015). Therefore, women salaries are less as compared to men salaries. In such occupations women participation is only 38.22%, however, men participation is 61.78% (Department of statistics, 2015). Therefore, this unequal distribution effect negatively on women self-sustainability. Furthermore, in labour force participation, female-to-male ratio is 0.59, professional and technical workers this ratio is 0.77 while in estimated earned income female-to-male ratio is 0.51 (Buang *et al.*, 2015). These issues are more in Kedah and Perlis states of Malaysian. That is the reason, level of poverty is more in Kedah and Perlis has high poverty.

Kedah state has 5.3% and Perlis state has 6% poverty (Department of Statistics, 2015). Commonly, females have higher unemployment and stagnant performance (Lewandowska-Gwarda, 2018). Nevertheless, through research and development, the labour productivity can be improved in long-term (Dubauskas, 2018; Stoklasova, 2018). However, in this situation, AIM is playing vital role with the to decrease the poverty level and gender discrimination while enhancing the level of women self-sustainability (Amanah Ikhtiar Malaysia, 2014). It provides various services such as small loan and training to promote women micro enterprises along with self-sustainability (Al-shami, Razali, & Rashid, 2018). Additionally, the role of Malaysian government for supporting women self-sustainability through micro credit programs is important by distributing funds through several ways for supporting poor people (Sriram & Mersha, 2006). Firstly, the

---

\* Corresponding author. Tel.: +48 34 3250 330;  
E-mail address: beata.slusarczyk@wz.pcz.pl

current study contributes by introducing government support as a moderating variable to enhance women self-sustainability and to enhance the positive effect of AIM. Secondly, this study covered Kedah and Perlis which is not formally documented by any study for examining the relationship of AIM and women self-sustainability.

## 2. Literature Review

The aim of various microfinance institutions and AIM is to reduce the poverty level by facilitating economic activities of poor people (Misnan, Noor, & Ramli, 2017). Micro enterprise generates income which enhance the women self-sustainability. Successful entrepreneurs have distinctive common attributes (Alroaia & Baharun, 2018). It also creates decision making power which enhance the social empowerment (Faizan and Haque, 2016; Mayoux, 2005). Thus, micro enterprise as a mediator has a major role to reduce poverty and enhance women empowerment. AIM provides various services such as financial services (small loans) as well as non-financial (training program) services to facilitates women micro enterprise for utilizing credit in better way (AIM, 2014). Through these financial and non-financial services, AIM tries to empower women community and increase quality of women self-sustainability. The combination of both loan and training is most important to run micro enterprise (Hameed et al., 2017). Loans help in establishing firm while training helps in effective running of micro enterprises. However, sometimes, credit/loan shows negative consequence when poor people use it unproductively (Hameed, Mohammad & Shahar, 2018a). Nevertheless, sufficient loan supports entrepreneurial performance (Gatewood et al., 2004; Ojo, 2009). Interestingly, loan aids entrepreneurs, especially women by often increasing income, investment, output and welfare of entrepreneurs (Kuzilwa, 2005; Peter, 2001). Thus, it has significant contribution in quality of women self-sustainability. Furthermore, credit has a positive impact on performance across the world (Hameed et al., 2017). Positive performance through loan from AIM enhances the income of women which ultimately increases the economic and social empowerment of women along with powered decision making (ibid). Thus, loan from microfinance institutions enhance the women social and economic empowerment which is positive indication towards women self-sustainability. Moreover, training is another aspect but in 1990, very little was offered to microfinance beneficiaries (Nieman, 2001). Nowadays, it is a significant tool adopted for enhancing micro-enterprise as it has significant positive relationship with micro enterprise success (Hameed et al., 2017). Nevertheless, there are failure in business due to the lack of skills (Radipere & Van Scheers, 2005). Microfinance institution's clients are unable to use microfinance factors properly because they do not have unique abilities (Karnani, 2007). However, training programs through AIM are most important to develop a reasonable level of sustainability among women community in Kedah and Perlis.

Government support has significant positive association with the attitude towards entrepreneurship (Sadeghi et al., 2013). Different agencies in Malaysia are now concentrating to distribute funds in different ways (Sriram & Mersha, 2006). In literature, the government roles as well as various activities towards encouragement on entrepreneurship are significantly related (Carayannis et al., 2003; Klapper, 2005). Therefore, government support is most influencing factor towards women self-sustainability. In this study, government supported is used as moderating variable between AIM and women self-sustainability. Based on literature, theoretical framework of this study is developed.

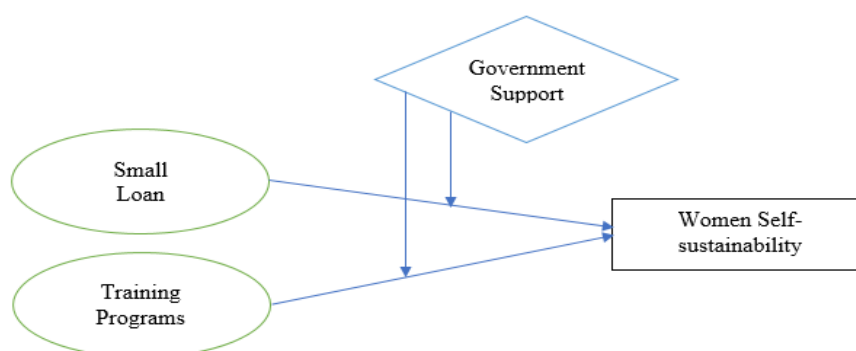


Figure 1. Theoretical Framework of present study

- H1. Small loan has significant positive relationship with women self-sustainability.*
- H2. Training programs has significant positive relationship with women self-sustainability.*
- H3. Government support has significant positive relationship with women self-sustainability.*
- H4. Government support moderates the relationship between small loan and women self-sustainability.*
- H5. Government support moderates the relationship between training programs and women self-sustainability.*

## 3. Research Methodology

Research developed critical realism ontological stance as the study falls under the scientific research paradigm using quantitative analysis. Since, the research revolves around microcredit organization therefore the primary data is gathered from the beneficiaries of AIM using credit and training related services. The research design is cross-sectional

as data is collected in one-time interval (Haque, Aston, & Kozlovski, 2008; Imran, Aziz, & Hamid, 2017; Imran et al., 2018). For the determination of sample size, the approach of Krejcie & Morgan (1970) table was adopted to calculate a sample size for drawing logical conclusion. Total beneficiaries of AIM in Kedah and Perlis combined (28,039 + 22,212=50,251) is target sample while the women participants are 60% of total. Thus, the total women beneficiaries are (50,251\*60%) 30,151. According to Krejcie & Morgan (1970), the sample size should be 380 when population is in range of 30,000 and 40,000. Hence, the adequate sample size is 380 beneficiaries of AIM are studied. Moreover, area cluster sampling is used to reach 380 target audience as it is suitable technique when the population spread on a wide area especially, non-availability of sampling frame then area cluster sampling is acceptable (Sekaran & Bougie, 2012). The questionnaire is adapted from previous studies hence, reflecting the reliability of research instrument. For women self-sustainability (dependent variable) scale items are adopted from Gangadhar and Malyadri (2015). For independent variables (small loan, training programs) scale items are adopted from Bernard, Kevin and Khin (2016). For moderating variable (government support) scale items are adopted from Kgagara (2011). Using PLS 3, measurement model assessment and structural assessment was done through factor loading, Cronbach alpha and composite reliability while Average Variance Extracted (AVE) was carried out for internal consistency and discriminant validity for external consistency. Minimum threshold was attained as the incurred values were above 0.7 value while square root of average AVE is greater than all incurred values therefore discriminant validity is attained, further confirmed by Heterotrait-Monotrait Ratio.

#### 4. Research Result

Hypotheses was tested in structural model using SmartPLS bootstrapping technique while t-value (minimum 1.96) was examined to reject or not the hypotheses. Moreover, the relationship direction between variables of interest was examined through path coefficient. Table 1 shows the results of structural model assessment that the independent variables (a) small loan (SL) and (b) training programs (TP) have significant relationship with women self-sustainability (dependent variable) (TP t-value = 4.065 > 1.96; SL t-value = 2.314 > 1.96, Table 1). Furthermore, from the government support has also significant relationship with quality of women self-sustainability.

Table 1. Structural Model Assessment (Results without moderator)

	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T Statistics ( O/STDEV )	P Values
GS -> WSS	0.246	0.238	0.078	3.141	0.002
SL -> WSS	0.242	0.252	0.105	2.314	0.021
TP -> WSS	0.447	0.451	0.110	4.065	0.000

Considering moderating role of government support between AIM and women self-sustainability, it is found that it has significant influence on the relationship. Table 2 revealed that the moderating effect in both cases; small loan and training program in relation to women self-sustainability are significant (SL = t-value 1.970 > 1.96 and TP t-value = 4.451 > 1.96).

Table 2. Structural Model Assessment (Moderation effect)

	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T Statistics ( O/STDEV )	P Values
SL* GS -> WSS	0.146	0.142	0.074	1.970	0.049
TP* GS -> WSS	0.202	0.208	0.045	4.451	0.000

Since  $R^2$  value is 0.745, confirming that 74.5% variance in women self-sustainability (endogenous latent variable) is due to government support, small loans and training program whereas Table 3 showed effect size ( $f^2$ ). According to Cohen (1988), effect size ( $f^2$ ) 0.02 is small, 0.15 is moderate and 0.35 is considered as strong. In the current study small loan and government support has small effect size, however, training programs has moderate effect size.

Table 3. Effect Size ( $f^2$ ) of variables of interest

	f-squared	Effect Size ( $f^2$ )
Small Loan (SL)	0.090	Small
Training Program (TP)	0.234	Moderate
Government Support (GS)	0.079	Small

Finally, the quality of model was assessed through predictive relevance ( $Q^2$ ). From Table 4 confirmed the predictive relevance ( $Q^2$ ) is more than zero. As Henseler *et al.*, (2009) stated that the value of predictive relevance ( $Q^2$ ) should be more than zero. Hence, the current model has attained the required level of quality.

Table 4. Predictive relevance ( $Q^2$ )

Total	SSO	SSE	$Q^2 = (1-SSE/SSO)$
Women Self-Sustainability (WSS)	546.000	338.282	0.380

## 5. Discussion

The findings revealed that AIM is one of the most significant institute for women self-sustainability as its financial and non-financial services are most crucial for enhancing women self-sustainability, particularly in Kedah and Perlis. These services are key to the success of women micro enterprise. Results confirmed that small loans (financial services of AIM) has significant contribution to empower women community through income generating activities. Increase in income contributes towards enhancing the women self-sustainability, therefore, our finding is aligned with work of Mayoux, 2005 as evident that credit has significant contribution to empowerment and self-sustainability of women. On the other hand, training programs (non-financial service of AIM) has also significant positive contribution in women self-sustainability. Increase in AIM training activities will directly influence women micro enterprise programs, leading to generate income and eventually increasing quality of women self-sustainability. Thus, our finding support work of Mayoux (2005), Hameed et al. (2017) and Hameed et al. (2018a). These financial and non-financial services have direct effect on income generating activities, which has positive influence on women empowerment leading to women self-sustainability. Therefore, we support work of Hameed et al. (2018).

Figure 2. Government Support' moderating effect between small loan and women self-sustainability

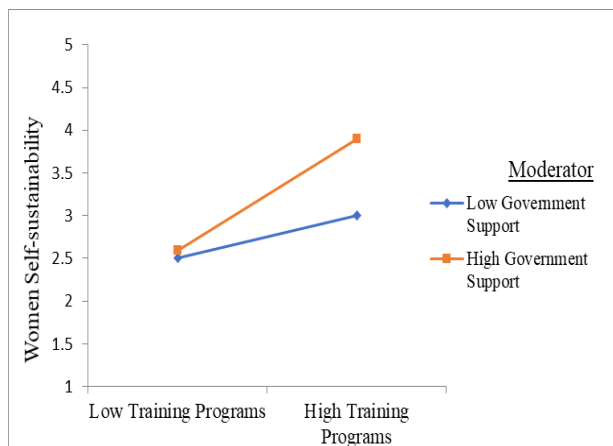
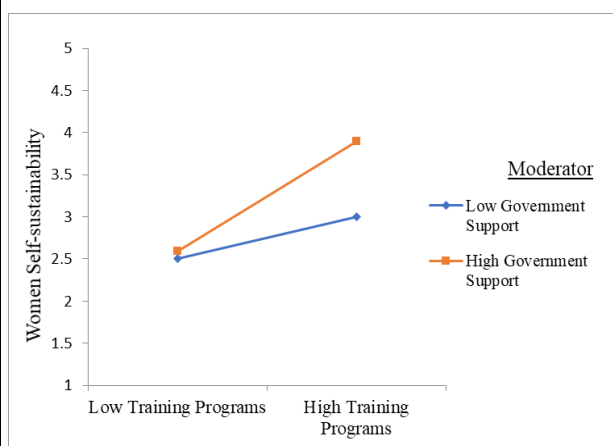


Figure 3. Government Support' moderating effect between training program and women self-sustainability



Moreover, regarding the moderating role of government support, it is found that Malaysian government support has significant positive influence on the relationship between AIM and women self-sustainability. This argument is also supported by prior study of Carayannis (2003) that government roles and various activities towards encouragement on entrepreneurship are significantly related. The moderating effect of government support is shown in Figures 2 and 3. Figure 3 shows that government support strengthens the positive effect of small loan on women self-sustainability while Figure 2 shows that it also strengthens the positive effect of training programs on women self-sustainability.

## 6. Conclusion

Based on the findings, it is concluded that AIM programs have effect on the quality of women self-sustainability in Malaysia. Additionally, the research majorly investigated and found the role Malaysian government in creating positive effect of AIM on Malaysian women community. Results confirm that AIM programs for poor people has great importance in empowering female community by reducing the poverty level and gender discrimination. In the past, AIM proved to be one of the major elements in poverty reduction and women self-sustainability. Nowadays, AIM is extending the services all over the Malaysia. Small loan facility (AIM service) is most important to run micro enterprises. Moreover, training programs enhance the women ability to utilize loan in effective manner by educating them to use it productively. Moreover, Malaysian government support has pivotal part in enhancing the positive role of AIM towards women self-sustainability. Various government programs and funding to AIM has decreased the poverty while automatically enhancing the women self-sustainability, particularly in Kedah and Perlis. Having said that, AIM could be vital program for the other governments, especially for emerging economies in the reduction of poverty. The microcredit organizations could be instrumental in empowering masses and promoting entrepreneurial ventures. As the social capital is most significant and its vulnerability should be reduced and increases the positive effect on poor women. It is recommended that the future researchers should add other services of AIM, such as saving products,

insurance products and SHG - Self-Help Group (social capital development activities) to current framework in order to further expand in multiple dimensions. Furthermore, the comparative analysis should be drawn to measure the role of AIM in improving the contrasting genders' performances.

## References

- Alroaia, Y. V., Baharun, R. B., Identification and Prioritizing Influential Factors on Entrepreneurial Success: A Case Study of SMEs in Iran and Malaysia, *Polish Journal of Management Studies*, Vol.7, No.2, pp.31-39, (2018).
- Al-shami, S. S. A., Razali, R. M., Rashid, N., The effect of microcredit on women empowerment in welfare and decisions making in Malaysia, *Social Indicators Research*, Vol.137, No.3, pp. 1073-1090, (2018).
- Amanah Ikhtiar Malaysia., *Laman web rasmi Amanah Ikhtiar Malaysia Ibu Pejabat AIM*. Retrieved from <http://www.aim.gov.my/index.php/kenali-kami/2013-03-14-14-20-42/sejarah.html>, (2014).
- Bernard, D. K., Kevin, L. L. T., Khin, A. A., Entrepreneurial success through microfinance services among women entrepreneurs in Sri Lanka: A pilot study and overview of the findings, *International Journal of Economics and Financial Issues*, Vol.6, No.3, pp. 1144-1150, (2016).
- Buang, A., Suryandari, R. Y., Ahmad, H., Bakar, K. A., Jusoh, H., Azman, H., Women and liveability–Best practices of empowerment from Malaysia. *Geografia- Malaysian Journal of Society and Space*, Vol.11, No.5, pp. 26-36, (2015).
- Carayannis, E., Evans, D., Hanson, M., A Cross Culture Learning Strategy for Entrepreneurial Education: Outline of Key Concepts and Lessons Learned from a Comparative Study of Entrepreneurship Student in France and US, *Journal of Technovation*, Vol.23, No.9, pp. 757-771, (2003).
- Department of Statistics., *Labour Market Information*. Retrieved from: [https://www.dosm.gov.my/v1/index.php?r=column/ctwoByCat&parent\\_id=436&menu\\_id=Tm8zcnRjdVRNWWlpWjRlbmtlaDk1UT09](https://www.dosm.gov.my/v1/index.php?r=column/ctwoByCat&parent_id=436&menu_id=Tm8zcnRjdVRNWWlpWjRlbmtlaDk1UT09), (2015).
- Dubauskas, G., National finance sustainability perception - the evidence from the last crisis in Baltics, *Journal of Security and Sustainability Issues*, Vol.7, No.4, pp. 635-642, (2018).
- Ekpe, I., Mat N., Razak, R., The Effect of Microfinance Factors on Women Entrepreneurs' Performance in Nigeria: A Conceptual Framework, *International Journal of Business and Social Science*, Vol.1, No.2, (2010).
- Faizan, R., Haque, A. U., The Relationship between Societal attributes, Feminine Leadership & Management Style: Responses from Pakistan's Urban Region Female-Owned Businesses, *European Journal of Business and Management*, Vol.8, No.23, pp. 171-191, (2016).
- Gangadhar, C. H., Malyadri, P., Impact of Microfinance on Women Empowerment: An Empirical Evidence from Andhra Pradesh, *Journal of Entrepreneurship & Organization Management*, Vol.4, No.2, pp.2-8, (2015).
- Gatewood, E. J., Brush, C. G., Carter, N. M., Greene, P. G., Hart, M. M., Women entrepreneurs, growth and implications for the classroom. USA: Coleman Foundation whitepaper series for the USA Association for Small Business and Entrepreneurship, (2004).
- Hameed, W. U., Hussin, T., Azeem, M., Arif, M., Basheer, M. F., Combination of Microcredit and Micro-Training with Mediating Role of Formal Education: A Micro-Enterprise Success Formula, *Journal of Business and Social Review in Emerging Economies*, Vol. 3, No.2, pp. 285-291, (2017).
- Hameed, W. U., Mohammad, H. B., Shahar, H. K., Pursuing Goal of Self-Sustainability but Leads towards More Instability: Challenges and Way Forward of Self-Help Groups (SHGs), *International Journal of Business and Tehnpreneurship*, Vol. 8, No.1, pp. 67-76, (2018a).
- Hameed, U. H., Shabbir, M. S., Raza, A., Salman, A., Remedies of low performance among Pakistani e-logistic companies: The role of firm's IT capability and information communication technology (ICT), *Uncertain Supply Chain Management*, Vol.7, (2018).
- Haque, A. U., Aston, J., Kozlovski, E., The impact of stressors on organisational commitment of managerial and non-managerial personnel in contrasting economies: Evidences from Canada and Pakistan, *International Journal of Business*, Vol.23, No.2, pp. 152-168, (2018).
- Henseler, J., Ringle, C. M., Sinkovics, R. R., *The use of partial least squares path modeling in international marketing. In New challenges to international marketing*, UK: Emerald Group Publishing Limited, (2009).
- Imran, M., Aziz, A., Hamid, S., Determinants of SME export performance, *International Journal of Data and Network Science*, Vol.1, No.2, pp. 39-58, (2017).
- Imran, M., Aziz, A., Hamid, S., Shabbir, M., Salman, R., Jian, Z., The mediating role of total quality management between entrepreneurial orientation and SMEs export performance, *Management Science Letters*, Vol.8, No.6, pp. 519-532, (2018).
- Kapila, M., Singla, A., Gupta, M. L., *Impact of Microcredit on Women Empowerment in India: An Empirical Study of Punjab State*. In Proceedings of the World Congress on Engineering, Vol. 2, (2016).
- Karnani, A., *Microfinance misses its mark*. Retrieved from Standford Social Innovation Review: <http://www.ssireview.org/articles>, (2007).
- Kgagara, M. R., *An Assessment of the Attitude towards Entrepreneurship Among Higher Education Students in Sedibeng District*, (2011).
- Klapper, L., *The role of factoring for financing small and medium enterprises*. The World Bank, (2005).

- Krejcie, R. V., Morgan, D. W., Determining sample size for research activities, *Educational and psychological measurement*, Vol. 30, No.3, pp. 607-610, (1970).
- Kuzilwa, J., The role of credit for small business success: A study of the National Entrepreneurship Development Fund in Tanzania, *The Journal of Entrepreneurship*, Vol.14, No.2, pp.131-161, (2005).
- Lewandowska-Gwarda, K., Female unemployment and its determinants in Poland in 2016 from the spatial perspective, *Oeconomia Copernicana*, Vol.9, No.2, pp. 183-204, (2018).
- Mayoux, L., Women's Empowerment through Sustainable Microfinance: Rethinking Best Practice, *Discussion Draft*, pp. 1-25, (2005).
- Misnan, S. N. S., Noor, R. M., Ramli, R. A., *The Role of Microcredit in Promoting Self-Employment in Urban Area: Lesson from Amanah Ikhtiar Malaysia (AIM), Malaysia*, ICOPS2017 eProceedings, pp. 140, (2017).
- Nieman, G., Training entrepreneurs and small business enterprises in South Africa: a situational analysis, *Education+ Training*, Vol.43, No.8/9, pp. 445-450, (2011).
- Ojo, O., *Impact of microfinance on entrepreneurial development: The case of Nigeria*. Faculty of Administration and Business, University of Bucharest, Romania, (2009).
- Peter, B. K., *Impact of credit on women-operated microenterprises in UASIN GISHU district, Eldoret, Kenya*. In P. O. Alila & P. O. Pedersen (eds), 2001, Negotiating social space: East African microenterprises. Retrieved from <http://books.google.com.my/book>, (2001).
- Radipere, S., Van Scheers, L., Investigating whether a lack of marketing and managerial skills is the main cause of business failure in South Africa: management, *South African Journal of economic and management sciences*, Vol.8, No.4, pp. 402-411, (2005).
- Sadeghi, M., Mohammadi, M., Nosrati, M., Malekian, K., The Role of Entrepreneurial Environments in University Students Entrepreneurial Intention, *World Applied Programming Journal*, Vol.3, No.8, pp. 85-98, (2013).
- Sekaran U., Bougie R., *Research methods for business: A skill building approach*, (6th ed.), West Sussex, UK: John Wiley & Sons Ltd, (2012).
- Sriram, V., Mersha, T., Facilitating Entrepreneurship in Sub-Saharan Africa: What Government can do, *Journal of International Business and Entrepreneurship Development*, Vol.3, No.1/2, pp. 136-151, (2006).
- Stoklasova, R., Econometric Analysis of SMEs in Eurozone, *Forum Scientiae Oeconomia*, Vol.6, No.1, pp. 19-29, (2018).

# Adapting leadership methods to global challenges: interactive leadership

Mohammad Jaradat<sup>a</sup>, Sergiu-Dan Iurian<sup>a\*</sup>

<sup>a</sup>Valahia University from Targoviste, Bd.Carol I St., No.2, Targoviste 130024, Romania

---

## Abstract

Globalization is a driving force that can change the whole concept of leadership because it's ever changing variables. Human resources are probably the main direct beneficiaries of the process, therefore leaders cannot and should not ignore the needs of the ones they lead, especially in an evolving society. The purpose of the article is to demonstrate that leadership methods have shifted their attention and goals in the last years, due to globalization of the management of human resources, but also as part of the changing needs in the global economy, and thus the emerging of a new type of leadership: interactive leadership.

*Keywords:* leadership; globalization; human resources; challenges; tehnology.

---

## 1. Introduction

Leadership – is the process through which a person influences other persons towards achieving a common goal and guides the organization so that it can achieve cohesion and a higher level of coherence. (Northouse, 2000)

Globalization has proven itself as being the most important challenge for both an organization and its human resource. In this context, organizations need to take into consideration two crucial aspects (McChrystal, 2016):

- having the most talented asset at the exact location, moment and with the lowest cost;
- creating the best plan/product/service in the smallest amount of time, at the right time and with the lowest cost.

## 2. Managing human resources as part of the process

In the recent years however, due to the intense globalization, managing human resources has suffered major changes. Because of the branding process of the international organizations, whether its public or private sector, people are more and more attracted to work for them, to play their part into developing global brands, and thus international organizations have the advantage of hiring the most qualified labor force, to the detriment of small, local organizations. (Duret & Vladimirescu, 2014)

Global leadership principles must be applied flexibly, taking into consideration the context of each country. The rising interest for cultural diversity can be explained through the following mechanisms: urban areas have become inhomogeneous from a cultural aspect, due to migration and mobilization of labor force and the rise of the global organizations during the 80's and the 90's which were using various labor force and were developing in vast cultural regions. (Duret & Vladimirescu, 2014)

Managing diversity thus becomes the key point of leadership. The shape that some behavior features take is the result of mix cultural teams. In some cultures, work is viewed as a task rather than the result of teamwork therefore relationships between staff are viewed as a sign of weakness, thus strong leadership can reflect either a sign of strength in some cultures and weakness in others. When working teams manage to deal with their cultural differences it can often lead to having strong groups with an infinite potential of work. There are two major aspects that can ease the achievement of high performances regarding global teams (Goffe, 2010):

---

\* Corresponding author. Tel.: +40-723-353-466  
E-mail address: jaradat\_hadi@yahoo.com.



- team selection

Consists into choosing wisely the employees with the right skills, purposes and knowledge, but also it consists into knowing how to evaluate them, knowing how to eliminate organizational barriers and obtaining high level of cooperation between their leading staff. Another key factor regarding team selection consists into managing to convince team leaders to get involved more often, being able to get proper feedback from each team member, but also knowing how to prepare and support them, by clarifying their task, deadlines and responsibilities. (Adler, 2010)

- team leading

Team leading must start slow and finish with strength. More than that asking for support can sometimes facilitate some team behaviors encouraging participation and collaboration among individuals, but also highlighting the differences between them enabling discussions that can lead to a clear analysis regarding the key factors that contribute to the success of a team.

It should be recommended that within an organization there should be a clear set of basic rules that serve as assets into the cultural difference harmonization process.

It is important to acknowledge cultural origins and respecting them because it might fuel the performance of the organization accepting that each person can be different, accepting their cultural heritage, the fact that differences regarding personality and abilities might be more important than differences among cultures and last but not least eliminating critical views regarding stereotypes, can all assure the long term of an organization. (Adler, 2010)

### **3. Interactive leadership influences organizations in a new global economy**

Because of globalization we can no longer ignore the cultural sign of leadership. That being said there are vast differences between the styles of leadership that are accepted in some cultures and rejected in others.

If we look at different models of leadership but also at the differences between cultural rules, we can conclude that in this global world more and more often we see new tendencies emerge. Global leaders are the ones that act into a multicultural environment and could use some skills and attributes such as: charisma, skills for teamwork, openness to change, interest toward the political life but also to the socio economic state of their country. Abilities to develop good relations with humans belonging to other cultures, adaptability to new situations and abilities to work into a multicultural team can also be part of the skills and attributes of the global leaders. (Schraa & Trompenaars, 2006)

Even though some personal qualities might increase their chances of succeeding as global leaders, there is also a specific set of organizational qualities that are at the base of success of an organization. Generally speaking an organization with a huge international success has the following characteristics:

- a large number of employees of different nationalities than the one of the organization itself
- huge investments outside the country of origin
- an extensive decentralization of power among international subsidiaries
- well-represented managers in the board of directors of the organization
- vast experience into developing activities abroad, experience belonging to members of the organization
- members of the organization that have international experience as a foundation stepping stone in their career path (Covey, 1990)
- the openness of the organization regarding the quick promotion of employees of different nationalities

For testing the skills of different candidates for foreign job openings there should be procedures more or less formal that test their openness towards a global multicultural organization. Often candidates are selected based on their performances within the organization that is based in their home countries, but then find themselves into difficulty when working in an international environment. Candidates should go through a professional training program before being sent abroad. This professional training program should teach them about organizational culture and the ways that a global career might help their advance, especially when working into different cultures and environments.

Leaders must create multicultural communities establishing an organizational culture that extends beyond barriers that the differ people and they must be able to offer guidance signals towards values and skills that can be easily understood by different cultural groups among staff.

Interactive leadership mainly refers to confirming the assumption of external influences on the structure of the organizations. Organizations can adapt to external changes which therefore develop structural characteristics such as:

a) organizational complexity – is defined as the number of occupations within the organization and their level of professionalism. It is a structural feature that is connected with the capacities of an organizations to adapt to environmental changes. Leaders permanently look for changes in the external environment and try to adapt. (Slater, 2009)

b) decentralization – employees of inferior rankings which are often more aware of the need to change are in fact excluded from the decision making process which should take into consideration their opinions as well.

Authority centralization in the superior rankings of the organization can be an obstacle in the way of change.

c) flexibility – when a major part of the activities develop among the organization are based on strict rules, adapting becomes more slow and more difficult to achieve, opportunities of change are no longer correctly received. A high level of task regulation can be a obstacle for change.

From the analyses of the way that structures can adapt to environmental conditions, we can review of the definition itself of the organizations, viewing them as a conglomerate of jobs, activities and roles that articulate themselves around two key functions implementing the most advanced professional technology regarding the organization and the environmental challenges of the outside of the organization. (Mardar, 2013)

Therefore, old leadership methods are no longer adequate for the new situations in which organizations find themselves into. New aspects redefine leadership such as:

- 1) its essence – what should leaders do?
- 2) its processes – how should leaders do it?
- 3) its purposes – why should leaders do it?

#### 1) What should leaders do it?

Three main facts affect what leaders do:

- a) the need to control change in parallel with the day to day leadership of the organization

For most of the leaders finding success formulas has been a constant difficult path especially when it comes to developing well harmonized policies. Nowadays this becomes more difficult because leaders must still keep their organizations walking but at the same time, as much as possible, they need to transform them. This requires a vision and a profound understanding of internal and external forces that can represent either serious threats or new opportunities for the organizations. This transformation implies the mobilization of the whole organization towards finding new competences and resources available in the future. Therefore, leaders must offer new advantages that will both help their organizations succeed and help transform it to a new one.

- b) the more and more rising influence of technology

The impact of technology is limited mainly to increasing the level of productivity among organizations.

- c) the concern for a larger and more fair leadership of processes and competences

The old role of leadership required that each compartment of an organization should function as the global strategy of the organization dictates it. Therefore, both integrating processes “part by part” but also integrating process as a whole had a major importance. The new leader must do the same things but viewed from two different perspectives:

- the first one is being able to manage more efficiently the processes that come together from different functions.
- the second major change refers to competences, because today efficient developing of each function is just a part of the daily activities, the main part becomes developing competences for the businesses of tomorrow, the future of the organization that basically makes it more competitive in a changing environment.

#### 2) How should leaders do it?

There are generally three forces that influence the leadership process:

- Developing new organizational systems of leadership with reduced hierarchies

The diversity and complexity of the new organizations, together with the need of taking quick action measures more rewarding have diminished in a great way the importance of hierarchic leadership based on command. More and more often the mission of the new leaders is to prepare the grounds for the exercising the leadership among long ranking levels of the organization.

- Raising the number of alliances and unofficial networks

Leadership must also function in the new structures and unofficial extend allegiance from the need of adopting new methods of competitive approaches, solutions and technological requirements that define the competitiveness of an organization. The difficult task of leadership in their case consists into finding common grounds for a common purpose in defining a common strategy and engaging into common actions.

- The constant modifying of public values and claims

The general values and claims of the public have shifted their goals in time. At first there was tendency to evaluate by size rather than performances, then the attention shortly took a shift towards performances, but finally the public attention was oriented to decisive performances that meant clear needs towards either products or actions of a decisive nature, so that the public can be witness to transforming of something.

#### 3) Why should leaders do it?

Leaders should want to find themselves into a new era because the general population is on a rise. Therefore, their task is constantly oriented into managing two major requirements from the global system:

- -creating new sustainable long term jobs
- -contributing to the social integration of their workforce – as shown above, cultural differences might be an obstacle but they can surely be an asset if managed properly. Multicultural teams can be very productive and efficient, therefore society plays a role into shaping the individual, but also individual plays a role into shaping society.

Finally the “what”, “how” and “why’s” are the basis for resolving each plan of action but the leaders difficult task is to anticipate, to adapt and to foresee the variables the might influence their organizations short and long term plans.

The technological changes from the last decades have lead to a more interdependent world with a fast growing rhythm. This fact has created a state of *complexity*. Complexity produces a situation that is fundamentally different than the complicated challenges from the past, complicated problems that required a great deal of effort, but, eventually, that lead to predictability.

Complexity means that, despite all of our skills, despite all the high number of possibilities of tracking and measuring something, some sort of situation, it still is much less predictable. This unpredictability is fundamentally incompatible with reductionist managerial models built around planning and around predictions. The new environment requires a new approach.

In regards to the fundamental distinction made above, we can therefore apply this differences when it comes to human resource managing different fundamental structures that separate hierarchical structures in the way they deal with teamwork. The old ones have roots into the old way of predicting things which can be useful when executing a plan a applying procedures that were planned in advance, but which become less efficient and less adaptable.

The modern way of dealing with things in regards to human resources is to offer a higher level of connectivity based on trust and mutual purpose, creating teams that have the ability to resolve problems that could not have been anticipated by a single person (manager), solutions being provided as a result of interactions and being offered from bottom up than the other way around. Teams are not the only response into dealing with the current leadership challenges, cooperation between the different compartments of the organization, but also allegiances playing their part as well.

## Conclusion

Adapting leadership methods to global challenges require interactive leadership, but interactive leadership is not an easy process to handle even though it might look simple at start. Like proven above the society needs have changed from being volume oriented to being effective quality oriented. For effectiveness to go hand in hand with interactive leadership there needs to be a synergy oriented shorter plan that helps leaders transmit their visions and goals to both low and high ranking employees, from different cultures in a short amount of time. A rather increased level of freedom of action among employees is also recommended, because it increases the chances of cooperation, together with a little bit of guidance towards global acceptance of different cultures as new environments to work in, or different teams of different nationalities that need to achieve better results through cooperation.

## References

- Adler, N, *Cross Cultural management*, Harvard: Business Press Books, (2010).  
Covey, S.R., *Principle-centered Leadership*, London: Excellence, (1990).  
Duret, G-N., Vladimirescu, T., *Leadership: între strategii și performanță*, Galați: Zigotto, (2014).  
Goffe, R., *HBR's 10 Must Reads on Leadership*, Harvard: Business Press Books, (2010).  
Mardar, S., *Leadership organizațional*, București: Univ. Națională de Apărare „Carol I”, (2013).  
McChrystal, S., *Echipa de echipe: noi strategii de leadership pentru o lume complexă*, București: Publica, (2016).  
Northouse, P., *Theory and Practice*, London: Print Hall, (2000).  
Schraa L., Trompenaars F., *Responsible leadership*, Canada: Routledge , (2006).  
Slater, R., *Secretele leadershipului*, București: All, (2009).  
<https://www.ted.com/topics/leadership>

# The importance of cultural marketing in evaluating creative personnel

Sergiu-Dan Iurian<sup>a</sup>, Mohammad Jaradat<sup>a\*</sup>

<sup>a</sup>*Valahia University from Targoviste, Bd.Carol I St., No.2, Targoviste 130024, Romania*

---

## Abstract

Culture is known as the product of human activities and thinking, therefore culture consist into various numbers of concepts containing science, beliefs, arts, customs, etc. Thus unlike any other domains, culture needs a specific type of marketing that is adapted to its special cultural products and services. In the cultural businesses the most important role goes to the creative personnel, therefore this special type of personnel will require special means of evaluation. The present article aims to demonstrate the importance cultural marketing in evaluating creative personnel, because creative personnel acts like both productive personnel and marketing staff at the same time. Thus evaluating creative staff should take into consideration their ability of promoting culture.

*Keywords:* culture, cultural marketing, creative personnel, evaluating creative personnel, creative mindset.

---

## 1. Introduction

The term culture refers to a complex concept that leaved through the ages due to various interpretations that gave different opportunities of growth. Ever since Cicero and later on Voltaire, the term culture was perceived as “valorization specific to the human spirit”, but also as a term referred to as something that describes “cultivating” or “growing”. (Gauntlett & Thomsen, 2013)

The definitions of culture widely refer to this word as being the result of products and services given by human thinking.

A first definition of culture would have to recognize both the abstract and material elements of culture. Culture influences attitudes, values and personalities around the world, religious preferences sets borders between individuals and between they will act, think. We can therefore refer to these aspects as being cultural rules. (Gauntlett, 2011)

The need of engaging people into cultural activities becomes the basis of human development, and it comes as a package deal with the need of correctly evaluating them once they become part of the cultural process.

## 2. The importance of culture as science

As previously discussed culture can be understood as a learning process, in which individuals voluntarily take part and one that gives perceptions, preferences and behaviors’ either through different groups (e.g.: dance crews) or social institutions (e.g.: museums).

Culture is passed away from one generation to another, it’s adaptive, it can be tangible or intangible, and it’s usually transforming as it evolves.

The content of culture will materialize under the form of either material culture creations (usually tangible creations) or immaterial culture creations (abstract creations such as: ideas, knowledge, opinions, values, rules, symbols, etc.). (Hawkins et al, 1983)

Culture can be understood from two different perspectives:

- one perspective that refers to culture as a service delivered to society;
- culture can also be understood as complex system with variables as the ones shown above, a system that encourages creative activities and their promotion to a public through an organization, making it a cultural product.

---

\* Corresponding author. Tel.: +40-757-047-252  
E-mail address: iurian\_sergiu@yahoo.com.



Fig. 1. A model of culture (adapted from Sørensen et.al., 2010)

This adapted model shows culture as being at the center of four major characteristics of society such as:

- **being** at the core of :
  - a) traditions;
  - b) identities;
  - c) roles.

This means that culture *plays* a major role in the individualization of each nation, religion or ethnicity. Culture can also be individualized based on the cultural institutions it refers to. This also means that cultural people (as in people who are involved in the promotion of culture) are the ones that have to *think* the ways in which culture can be an entertaining and useful experience.

- **knowing** the full history of:
  - a) experiences;
  - b) knowledge;
  - c) meaning

This translates into the fact that culture is a result of the historical evolution either upon a group of individuals, or upon individuals seeking to contribute to the cultural heritage. Each individual sometimes expresses directly or indirectly his meaning on this world through culture. Whether we refer to an individual, or a group of individuals, they all possess the ability to develop knowledge, experiences or new meanings that will affect the cultural heritage in one way or another. Culture thus becomes a platform for social heritage.

- **having** different:
  - a) environments;
  - b) materials;
  - c) media access.

This means that culture is an expression of the *making* process. In other words, culture is an translation of knowledge through different platforms such as environments, materials or media. Having culture is one thing, but being able to share it is a completely different discussion

- **doing** things that will involve *sharing* culture such as:
  - a) activities;
  - b) developing relationships;
  - c) practices

This means that culture need to be shared in order to be perceived as something that identifies individuals, objects, groups of individuals, nations etc. Therefore, the process of being, knowing and having has a certain ending, by passing on knowledge. Sharing culture ultimately means sharing the cultural products. It can also be viewed as the beginning of

the process, if we perceive doing all these activities, relationships and practices as a source of origin for the cultural movement.

As a science, culture becomes extremely important because it does not only develop and transmits means of developing cultural products such as art works, but it also can be a science that can offer more understandings towards what are the characteristics that define a certain area, or group of people, whether we refer to an ethnic group, or a nation as a whole etc. Culture becomes thus a binder between different individuals, a science that can offer an infinite amount of understanding on how society works and interacts.

From a legal point of view these cultural institutions are to be understood as “a public or nonprofit organization that is engaged into cultural enriching, intellectual, scientific, environmental, educational or artistic enriching within communities. Cultural institutions also can consist into aquatic organizations, botanical, historical, preserving patrimony, public libraries, museums, artistically associations or zooidal ones.” (Oregon juridical dictionary)

Cultural institutions can be classified from various perspectives depending the context or their activities, however understanding the way human resources function within this type of organizations means understanding both the definition of the term culture and the way human resources management works (by the importance of the creative personnel).

### **3. The importance of cultural marketing**

Cultural marketing is a widely referred to as a special domain of marketing that has emerged due to the extensive development of culture and in order to promote the cultural products and services.

Cultural marketing will assist any cultural organization into achieving its mission. Cultural marketing is also known as “marketing of arts”. This process need to be adapted from one organization to another, from one type culture to another. Therefore, the main organizations which this process can be applied to are (Pride & Ferrell, 1985):

- religious organization;
- research and education organizations (cultural ones, which different from the specific educational organizations);
- NGO’s specialized in promoting cultures (foundations which have special purpose into promoting culture);
- museums, memorial houses;
- libraries, archives;
- publishing houses;
- theatres and operas;
- cinemas;
- expositions and special institutions organizing cultural events;
- arts manufactures and traditional arts associations;
- individual artists or special artists’ associations;
- bands and other forms of artist groups;
- in the new modern times we live in, culture has been given an important commercial meaning.

This means that in order to survive a cultural organization of any kind needs to address itself to a specific type of consumer and needs to adapt itself to a very complex process that involves a high number of variables. For instance, cultural organizations need to be perceived as being contributors to (Miyata, 2013):

- education – by transmitting the main instruments for understanding and appreciating culture;
- the institutionalization of the ways for spending free time – this means that nowadays people are very selective when it comes to spending their free time, because of the various ways of doing it. Culture plays a huge part in this process because it can both influence it, or give options to individuals acting therefore as a supplier of products and services;
- technical support for the mass distribution of the cultural products and services.

Cultural marketing operates thus into various fields with a large number of opportunities regarding the satisfying client needs.

Regarding client needs it is very important to understand the concept of being a culture client, which means being either a spectator or directly involved in the cultural process.

The creative personnel involved into cultural process has also double role, being both creators of arts, and, at the same time, being the main ambassadors for this process.

Creative personnel, being involved into the marketing process need to take into consideration the consumer needs and motivations regarding culture such as:

- renowned creators or band or artistic company;
- the pleasure of listening to music;
- the desire to relax;
- advertising made for the show;
- recommendations made by parents and friends;
- favorable art criticism;
- the desire to go out with your parents and friends to the show.

All cultural organizations are faced with the difficult task generating new marketing strategies due to the change of the environment in which organizations prosper:

- the consumer has diminished his leisure time;
- expanding options for consumer diversification;
- the wider global exposure of cultural products worldwide;
- changing public funding methods;
- the distinction between popular and supreme culture is increasingly blurred;
- organizations are at the end of their lifecycle.

#### **4. The importance of creative personnel**

The importance of creative personnel in culture can be specially defined by the importance of organizational culture in arts. Being able to build an organizational culture for a cultural institution consists into creating a cultural product or service. This process has a specific original nature when it comes to culture. The cultural product or services are designed into a special environment which has its own history, values, boundaries and ultimately affects the way the organization understands and appropriates a specific system of values. (Runco, 2013)

In the center of this processes, the one of creating value and the one of creating an identity for an organization, stands a specific type of personnel. It is easily to be understood why this type of staff is a creative one, made of people with a high level of cultural understanding. Creative staff members have difficult tasks of:

- understanding client needs;
- anticipating client needs;
- creating products and services;
- understanding the environment in which their organization operates and creating added value;
- promoting cultural products and services;
- evaluating themselves in order to either improve what can be improved, or dispose what is disposable.

Creative personnel thus have to manage a difficult process between the needs of being an artist, and the expectations of the general public, (consisting into public actors – trustees; consumers). (Donald, 2013)

Managers of creative personnel have the difficult task of being leaders of this complex cultural process and specific type of staff. Their work consists into being able to give stimulants and performance bonuses to their personnel, a work that is generally not easy because it needs to satisfy both financial and nonfinancial rewards that creative personnel need.

Leadership into cultural organizations needs to address the main goals that each creative individual has which can be defined as Maslow states into five basic needs:

- psychological needs;
- security needs;
- social need of belonging to a group;
- esteem needs of respect and trust;
- personal development.

#### **5. The importance of evaluating creative personnel**

The necessity of a creative mindset especially when it comes to culture is undoubtedly high. The creative mindset has been during ages the main thing that has made the human race evolve or even survive. Therefore, stimulating a creative mindset especially to cultural activities, is a luxury that human race must entertain. (Runco, 2013)

This comes with a package deal of certain level of ease when it comes to the pressure of generating results. A creative mindset only prospers in certain environment where all its need and desires are fulfilled and where the level of pressure is relatively low.

Managers cannot force creative mindsets into generating products and services especially when it comes to cultural ones thus evaluating the creative personnel requires first and foremost evaluating their needs, the way in which the cultural organization can fulfill them and only then the results generated can be submitted to evaluation.

We can then easily pick different ways of evaluating creative personnel by their success, or more exactly by the way their work is being perceived and understood:

- on one hand we'll have a scenario where evaluating creative mindsets is done by the perspective of success triggered by their results;
- on the other hand we'll have a scenario where creative personnel hasn't been generating the results which the interested parties were looking for;

This also means that the marketing aspect of the creative work plays a huge part because maybe a cultural product or service has been created properly, but, from a various numbers of reasons, hasn't been transmitted properly to the clients. Cultural marketing therefore offers an alternative to cultural managers into evaluating creative personnel, because it operates as "the last stand" between successful cultural personnel and unsuccessful. Sometimes a good



marketer can hide its lack of creativity when it comes to their products or services under their great ability of communicating and promoting something that doesn't necessarily added value.

It is thus that cultural marketing can make the difference between the success or the failure of a cultural institution.

Evaluating the creative mindset should focus on (Gauntlett & Thomsen, 2013):

- seeing whether the individual's attitude towards the world is defined by curiosity, essential questions desires to share, to produce, or to play. Children usually have these attributes, therefore a creative mindset should be able to sustain them, to constantly nurture, or keep the flame of the "inner child" active.
- seeing whether the creative mindset is still active. This means that a creative individual never loses interest in their creative subject, it can reduce its intensity towards it, but lose it. This is why evaluating creative personnel should focus on seeing if the curiosity level is only at a low point or whether it has disappeared.
- seeing if the creative mindset has a high level of a playful behavior. This means that creative individuals are usually tempted to spend their free time into the same world creativeness regarding their designated subject. They tend to find different approaches towards the designated subject and approach them with a playful behavior.
- seeing if the creative personnel is able to fuel their desire to learn with expert help or by self-education. This means that even though creativeness might be understood as an individual process, nevertheless it is far from being so. Creativeness must have a knowledge basis which is defined by expert help, thus one cannot be creative regarding culture unless he/she has a certain knowledge and understanding about their designated cultural process.
- seeing if the creative personnel works in an environment that promotes creativeness, risk taking and also collaborative activities. This means that a creative mindset will usually look for an environment (space or a group of people) which stimulates its creativity knowledge regarding their subject and thus has an open mindset. This also can be translated through the idea that culture rarely was born from a cave, but from an open mindset that prospered into a rich (full of potential) environment.
- seeing if the creative personnel has generated more than one scenario where their idea might prosper. This means that in order to be successful a creative mindset must be open to the idea of trying, even with risk of failing, therefore creative personnel should be evaluated by their ability of trying more than once.
- seeing if the creative mindset is able to accept diversity. This means that creative personnel can prosper only when they are able to identify their consumers and in order to do so they must first cope with the challenge of understanding diversity, accepting it and knowing who to address and how to do it. Thus creative personnel should have a high level of acceptance regarding society.

All the aspects explained above could be evaluated from the different quantitative and qualitative approaches. Nevertheless, the results should be the same, in other words each of the points shown above should have high levels among creative personnel. If the levels are low in either of the cases shown above, there is a risk that the creative personnel is not as efficient as should be and therefore immediate action is required, if not the cultural institution risks failure.

However as shown above cultural marketing plays a huge role and comes as a helping tool for those (either staff or managers) who can or want to hide their lack of creativity behind a well-constructed process. Or on the other hand, cultural marketing can be an obstacle for a creative cultural mindset that is not able to communicate its work. (Durkheim, 1938)

Thus cultural marketing should also be considered as an attribute of creative cultural personnel and included in the process of evaluating the creative mindset of the cultural personnel. (Gauntlett, 2011)

## **Acknowledgements**

Culture is an abstract term used to define a number of values and contributed to the evolution of mankind. Culture can also be viewed as a science seeking to offer solutions towards understanding and improving the social heritage, offering solutions towards understanding the cultural products.

Marketing plays a huge role in promoting culture. Cultural marketing is based on the ability to promote but also to understand the needs of artists and expectations of the public.

When it comes to culture, creative personnel plays a huge part in developing new products and services of culture. Creative staff members usually have certain needs in order to offer results. Creative personnel is defining for cultural institutions, but this does not mean that the creative process works into an absolute free environment.

Evaluating the work and the abilities of the creative personnel is a difficult task which should be made regarding certain key points, one of them being the ability of the creative personnel to promote, to present their work. The way the evaluation is made, ultimately affects the way creative personnel works and generates results.

The future will give us more and more ways of spending our free time. This means that cultural institutions will be working into environments more and more in a hostile environment, thus, the abilities of creative personnel become highly important because the quality of cultural products and services need to be better and better in order to compete with other ways of spending free time. Evaluating the creative personnel and cultural marketing become two imperative aspects that cultural managers must not ignore.

## References

- Donald, M., *Cognitive evolution: Implications for developing a creative mindset*, Billund: The LEGO Foundation, available at: [www.legofoundation.com](http://www.legofoundation.com), (2013).
- Durkheim, E., *The Rules of Social Method*, New York: Free Press, (1938).
- Gauntlett, D., *Making is Connecting: The social meaning of creativity*, Cambridge: Polity, (2011).
- Gauntlett, D., Thomsen, B.S., *Cultures of Creativity*, Billund: The Lego Foundation, available at: <http://cache.lego.com/r/legofoundation/-/media/lego%20foundation/downloads/cultures%20of%20creativity/cultures%20of%20creativity%20lego%20fonden%202013.pdf?l.r2=-1862253112>, (2013).
- Hawkins, D.I., Best, R.J., Coney, K.A., *Consumer Behavior: Implications for Marketing Strategy*, Texas: Business Publications, (1983).
- Miyata, Y., *Nurturing creative mindsets in the global community*, Billund: The LEGO Foundation, available at: [www.legofoundation.com](http://www.legofoundation.com), (2013).
- Pride, W.M., Ferrell, O., *Marketing: Basic Concepts and Decisions*, Boston: Houghton Mifflin, (1985).
- Runco, M.A., *Fostering creativity across cultures*, Billund: The LEGO Foundation, available at: [www.legofoundation.com](http://www.legofoundation.com), (2013).
- Sørensen, A.S., Ystad, O.M., Bjurström, E., Vike, H., *Nye Kulturstudier*, Copenhagen: Tiderne Skifter, (2010)

## Dimensions and indicators of quality management assessment in the context of sustainable development

Monica Aureliana Petcu<sup>a</sup>, Iulia Maria David-Sobolevski<sup>a</sup>, Irina Daniela Cişmaşu<sup>a\*</sup>

<sup>a</sup>*The Bucharest University of Economic Studies, Bucharest, Romania*

---

### Abstract

Sustainable business development, in an environment marked by strong dynamics that leads to changes of paradigms and meanings of the evolution of various components, generating constraints and multiple risks, is decisively conditioned by the quality of their management. Quality is a complex concept that can be defined by a series of quantitative and qualitative indicators adapted to the specificity of each entity's activity.

In the context of this paper, in the perspective of the sustainable development of enterprises, a brief presentation of the characteristics of the management quality assessment was considered, as a process with dynamics connected to the environment, with complex approach dimensions that imply specific reasoning, circumstantially relativized measurement and interpretation techniques, especially with benchmarks in maximizing the satisfaction of all those interested in their work, including communities, as well as environmental protection.

The research undertaken for this purpose has been finalized by proposing a set of indicators to provide, from the perspective of each stakeholder, sufficient arguments in the proper assessment of the quality of management and in making appropriate strategic decisions in the context of sustainable development

*Keywords:* sustainability; quality; management; performance

---

### 1. Introduction

Accelerating the changes in all environments, from the natural to the economic and social ones, and the prolonged economic and ecological crisis lead to connecting all the companies to the complex problems of sustainable development of their own activities, in the conditions of globalization. At the same time, the dynamics of the expectations of the stakeholders (clients, partners, investors, employees, community, etc.) requires continuous improvement of the quality of products/services, the efficiency and effectiveness of processes, the reduction of non-quality losses.

Between the arguments of any actor on the market, regardless of the size or area in which it operates, quality and innovation, especially eco-innovation, are required as fundamental factors of sustainable development.

As a vector of business excellence and a decisive factor in competitiveness, product quality is a fundamental business objective: "Quality of the product is not everything, but everything is nothing without quality" (Peters and Waterman - "In Search of Excellence") and the result of an integrated quality management system. The integrated approach to quality implies: the quality of products/services, the quality of processes, the quality of management, the quality of the workforce and the working environment, the quality of the results, the quality of the partnerships, etc. In this integrated system, the role of management is decisive, noting the dialectical interdependence between quality management and management quality.

---

\* Corresponding author. *E-mail address:* irina.cismasu@cig.ase.ro

## 2. Quality of management - content and assessments

The definition of quality implies certain difficulties due to the need to interpret a formalized system by another formalized system, this interpretation depending on the analyst's ability to find objective operational terms as appropriate as possible and their measurable levels. It is also necessary to delimit the intangible dimensions of quality by its tangible attributes.

In an integrated system of assessing the quality of management, particularly important are the ways of approach, taking into account the following:

- the quality of management is the result of a continuous upgrading process aimed at maximizing the satisfaction of stakeholders with specific benchmarks of evaluation;
- the evaluation of managerial quality from the perspective of the sustainability of the activity carries out a complex approach in relation to the holistic subsystems in this approach, for each of which there are certain qualitative and quantitative indicators;
- the quality of management lies in the quality of products/services, results processes and partnerships, across the value chain, each having its own reference system;
- the diversity of the system implies the correlation of economic, financial, social, cultural, ecological dimensions.

From the economic and financial perspective, the quality management assessment involves both qualitative analyzes, through which systems are approached, elements, their structural and conditioning relationships, are identified, and quantitative analyzes that allow relevant quantification. Consequently, the assessment of the quality of management on this important level with certain assessments, through usual indicators that reveal the performance of the enterprise with repercussions on the satisfaction of stakeholders, has been considered satisfactory to date, when the issue of sustainable development and the creative-innovative dimension, eco-innovative are becoming key factors in assessing the quality of management.

From the socio-economic perspective with complex socio-cultural dimensions, including consumers, employees and the community, management quality assessment implies specific reasoning, based on derived indicators, own measurement and interpretation techniques, involving subjective relativisms and interpretations.

From the customer's point of view, the quality expresses the benefit of consumption, compliance with its needs, the reference value for the buyer consisting of its maximum expectation, within its own budgetary constraints, and the value of the product/service as such is given by the degree of utility in meeting a need, depending on its budget constraints (utility/cost grade). From the point of view of the manufacturer/service provider, the quality expresses the attributes, the essential features that define the product/service, respectively the function it performs, giving it the capability to use and the costs involved (degree of function/cost) satisfaction. Exceeding consumer expectation, correlative with the provider's capabilities fitting, ensures quality management and business excellence.

A particularly important area, in terms of sustainability, is the ecological one. Strict adherence to environmental standards and the sustained effort of eco-innovation are stringent requirements that give quality to the managerial process, even if the economic and financial results appear modestly and gradually.

From any perspective or within any holistic subsystem, the quality of management is addressed, the key is to use a complex system of indicators to enable it to be valued in relation to stakeholders, including the community and environmental protection, as a circumstances for the sustainable development of the enterprise.

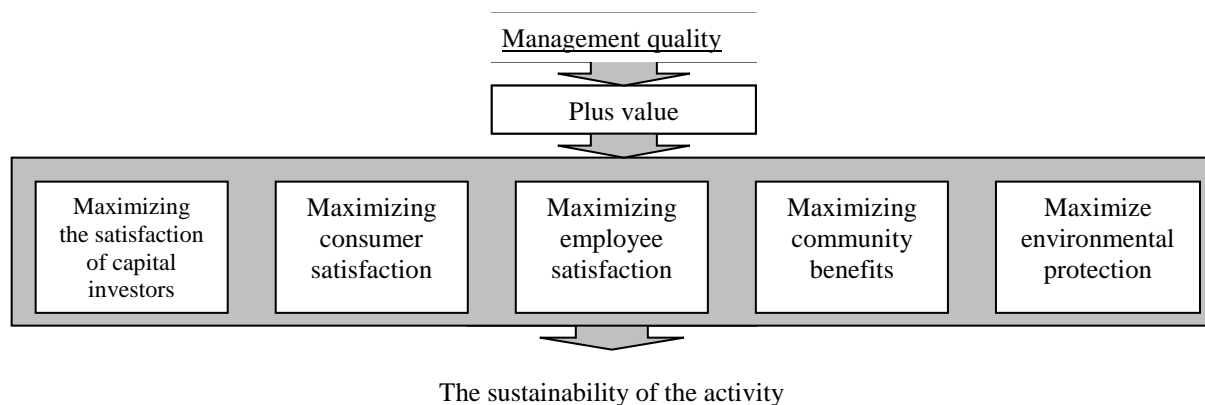


Fig.1. The approach of the quality management assessment in a sustainable perspective

### 3. Sustainability Performance Indicators

In a brief approach we present a series of indicators for the management quality assessment under the imperative of sustainability, structured in the presented context of the stakeholders:

- at the level of the capital investors

indicators	meaning
<b>Specific indicators</b>	
investment in scientific research and information technology	The orientation of investment efforts towards scientific research, in all its dimensions (from the fundamental one, to the application in production), and the information technology provide the premises of the adaptation to the dynamics and general progress, and at the same time its catalyst. The research results are generating superior added value, improving product and process quality, improving resource efficiency, with ecological valence.
innovative capacity	Stimulating the innovative capacities of human capital, expressed through the registration of trademarks, patents, licenses, product/ process innovation, with a high level of competitiveness and a sustained rhythm of technical progress, is a vector of sustainable development.
<b>Support indicators</b>	
turnover	A growing sales volume reveals the performance of the production and marketing activity by recognizing the value of the product/service offered by the consumer. Increasing sales, with an appropriate mix of quantity and price, is a condition for sustainable company development. The significance of the company at the level of the industry is appreciated by the size of the turnover. Companies with high market share ensure their sustainability in a dynamic, highly competitive environment.
profit	Achieving a significant and growing profit ensures self-financing of investments and increasing the indebtedness of a firm. This creates the financial resources needed to invest in projects with a high technological level, innovative, linked to the dynamics of the research in the field, which is the basis for a sustainable development.
return on investment	The decision to invest in a dynamic, complex, highly competitive environment requires, to ensure the capacity to capitalize on opportunities to maximize earnings and reduce risk, focus on investment project portfolios. A high return on capital invested in each project amplifies the synergistic effect of strategies, ensuring sustainable development.
the liquidity of the invested capital	Rapid recovery of invested capital allows the exploitation of new opportunities, synchronizations and even advancements in the rhythm of development of the industry, the elimination of opportunity costs and, implicitly, resources for the sustainable development of the firm.

- at the customers' level

indicators	meaning
Innovative products / services offered	Achieving innovative products/services with superior levels of value and expectation is an effect of management quality and the premise of sustainability.
Customer Satisfaction Score	Determination of satisfaction and changes in consumer satisfaction provides important information on the positioning of its products/ services in relation to consumer expectations and trends, which are milestones in substantiating sustainable development strategies.
Net Promoter Score (NPS)	Customer satisfaction assessment indicator, NPS is a reference in substantiating company strategies. A value tending to 100% reveals a maximum degree of customer satisfaction and their willingness to recommend the brand/product/service/store to others. Providing valuable products / services that exceed consumer expectations leads to increased demand, ensuring the potential for sustainable growth.
Customer Effort Score (CES)	A value in the proximity of the unit reveals great efforts in getting the product/service offered by the customer. The proximity of value 5/10 reveals the facility of acquiring the product, which will allow time and financial savings that will lead to customer loyalty. Increasing accessibility of products/services implies the imposition on the market, increasing sales, with consequences in the ability to sustain sustainable development.

industry benchmarks	Evaluating the position of the brand in relation to its competitors allows us to obtain relevant references in substantiating the company's strategies, putting the focus on efforts to gain competitive advantage over the whole value chain. This implies the implementation of quality management systems. Validating the brand's superiority on the market is an essential element of competitiveness as a condition for sustainable development.
brand attributes	The convergence between customer expectations and brand/ product/service attributes is a decisive factor in asserting them on the market and strengthening the market position of the firm. The similarity of perception of brand attributes at company and consumer level ensures customer loyalty, transformation them into promoters and sustainable development.

- at the level of employees

indicators	meaning
the optimal environment for using its own capabilities	The convergence between job requirements and individual capabilities is a condition of harmonizing employee interests and aspirations, with beneficial effects on innovative, efficient and sustainable company development.
fair compensation	Providing salary packages to satisfy the effort, being stimulating through the value generated individually, supports the effectiveness of the creative potential and the empowerment of employees as a sustainable competitive advantage.
safe working conditions	Job security enhances employees' involvement by eliminating absenteeism from focusing on physical integrity and improving work quality, focusing their attention on the production process. This is reflected in increasing productivity, capitalizing on creative and innovative skills, lowering the cost of accidents at work, staff litigation, with favorable effects on the sustainability of the work.
pleasant work environment	A pleasant work environment ensures physical, emotional and cognitive involvement. Reducing workplace stress is a prerequisite for increasing work productivity with effects on company performance. Happy employees have a creative, positive attitude and contribute to making team work more efficient. Pleasure to work in the right conditions favors employees' involvement, ensuring business success. At the same time, a pleasant work environment reduces the fluctuation of employees, with the company benefiting from the learning effect.
career development	The inclusion of employees in continuous training and professional development programs is the premise of increasing adaptability, creativity, innovative capacity, sine-qua non conditions of sustainable development.

- at the community level

indicators	meaning
the ratio between sponsorship and donations and turnover	Awareness of the need to engage in solving problems or in developing community projects, that exceed its resources, in ensuring a high level of welfare in the society in which it operates ensures the premises of an environment conducive to sustainable development.
investment in public-private partnerships	The development of public-private partnerships to achieve general interest objectives creates stimulating synergies for sustainable progress.

- from the ecological perspective

Indicators	meaning
eco-innovation	The creation of eco-innovative products/services and the innovation of processes with ecological valences are essential concretizations of management's concern in sustainable development.
efficiency of rational use of resources	The efficient use of resource ensures increased economic stability by reducing volatility in essential resource markets; limiting the risk of deficits and increasing competitive pressure; improving the economic health of key sectors enhancing long-term economic competitiveness. The efficient use of natural resources requires ecological fairness and sustainability.

the degree of environmental pollution

Reducing carbon emissions, increasing waste collection, making more use of renewable energy, efficient use of resource contribute to the prevention of dangerous climate change and are imperative to contemporary society circumscribed by the need for sustainable development. A priority objective in company strategies is to avoid natural imbalances, preserve the integrity and nature biodiversity and restore ecosystems, reducing vulnerability and increasing their resistance in a fair and sustainable development process. Reducing the anthropogenic pressure on biodiversity is now not only a condition for the sustainable development of enterprises, but also for the whole of humanity.

---

## Conclusion

Sustainable business development is influenced by the quality of its management. Driving efficiently processes, obtaining quality products/services, stimulating creativity and innovation, reducing pollution, converted to maximizing the satisfaction of stakeholder, are fundamental management responsibilities.

The dynamics of environmental changes and the imperatives of sustainable development require a permanent process of strategic approach and holistic planning with milestones in the quality of management assessment, with an ongoing progress. In this context, the assessment of the quality of the management is also a dynamic process in relation to the conditionality of sustainable development and the maximization of the satisfaction of the stakeholders. Identifying a system of performance indicators adapted to the specifics of the enterprise and linking to the dynamic imperatives of sustainability will provide a solid foundation for assessing the quality of management and strategic decisions in this area.

## References

- Abbott, W.E., Monsen, R.J., *On the measurement of corporate social responsibility: Self-reported disclosures as a method of measuring corporate social involvement*, Academy of Management Journal, volum 22, pp.501-515, (1979).
- Agle, B. R., Mitchell, R. K., Sonnenfeld, J. A., *Who matters to CEOs? An investigation of stakeholder attributes and salience, corporate performance, and CEO values*, Academy of Management Journal, volum (42), pp. 507-525, (1999).
- Basu, K., Palazzo, G., *Corporate social responsibility: A process model of sensemaking*, Academy of Management Review, volum 33, pp. 122-136, (2008).
- Bauman, Z., *Globalizarea și efectele ei sociale*, traducere în română de Marius Conceatu, București, Editura Antet, (2004).
- Bădescu, V. S., *Etica în afaceri*, Editura ProUniversitaria, (2014).
- Boatright, J. R., *Ethics and the Conduct of Business*, 3rd edition, New Jersey, Prentice Hall, Upper Saddle River, (2000).
- Buglea, A., *Analiză economico-financiară*, Ediția a II-a, Editura Mirton, Timișoara, (2011).
- Buglea, A., Lala-Popa, I., *Analiza economico-financiară*, Editura Mirton, Timișoara, (2009).
- Carroll, A. B., Buchholtz, A. K., *Business and Society: Ethics and Stakeholder Management*, 4th edition, Cincinnati, South-Western College, (2000).
- Charreaux G. , *Gestion financière*, Ed. Litec., Paris, (1991).
- Christensen, L. J., Peirce, E., Hartman, L. P., Hoffman W. M., Carrier J., *An Analysis of Ethics, CSR, and Sustainability Education in the Financial Times Top 50 Global Business Schools: Baseline Data and Future Research Directions*, Journal of Business Ethics No. 73 pp. 347-368, (2007).
- Dinu, E., *Strategia firmei : teorie și practică*, Editura Economică, București, (2000 ).
- Dinu, V., *Dimensiunea etică în afaceri*, Revista Amfiteatru Economic, nr. 23, pp. 7-10, (2008).
- Douglas T.,J., Judge W.,Q.,*Total Quality Management Implementation and Competitive Advantage: The Role of Structural Control and Exploration*, Academy of Management Journal, Vol. 44, No. 1, (2017).
- Drăgulănescu, N, Drăgulănescu M., *Managementul calității serviciilor*, Editura AGIR, București, (2003).
- Froman, B., *Manualul calității - instrument strategic al abordării calității (traducere din limba franceză)*, Ed.Tehnică, București, (1998).
- Guénou, R., *Autoritatea sacerdotală și forța regală*, Editura Herald, Bucuresti, (2005).
- Ionescu,G, *Cultura afacerilor*, Editura Economică, București, (2003).



- Kaynak, H., *The relationship between total quality management practices and their effects on firm performance*, Journal of Operations Management, Volume 21, Issue 4, pp. 405-435, (2003).  
<https://www.sciencedirect.com/science/article/abs/pii/S0272696303000044>
- Karia, N., Muhammad Hasmi Abu Hassan Asaari, *The effects of total quality management practices on employees work-related attitudes*, The TQM Journal, Volume 18, Issue 1, (2006).
- Lefter, V., Olaru, M., Isaic-Maniu, A., Pop, N., Popescu, S., Drăgulănescu, N., Roncea, L., Roncea, C., *Tehnici și instrumente utilizate în managementul calității*, Editura Economică, București, (2000).
- Mitchell, R. K., Agle, B. R., Wood, D. J., *Toward a theory of stakeholder identification and salience: Defining the principle of who and what really counts*, Academy of Management Review, 22, pp. 853-886, (1997).
- Mironciuc, M., *Analiza economico-financiară*, Editura Universității „Alexandru Ioan Cuza”, Iași, (2009).
- Nair, A., *Meta-analysis of the relationship between quality management practices and firm performance—implications for quality management theory development*, Journal of Operations Management, Volume 24, Issue 6, pp. 948-975, (2006). <https://www.sciencedirect.com/science/article/abs/pii/S0272696305001440#!>
- Nicolescu, O. (coordonator), *Sisteme, metode și tehnici manageriale ale organizației*, Editura Economică, București, (2000).
- Nicolescu, O. (coordonator), *Strategii manageriale de firmă*, Editura Economică, București, (1998).
- Pantea, M.I., *Analiza economico-financiară, instrument al managementului întreprinderii*, Editura Universității de Vest, Timișoara. (2017).
- Petcu, M.A., *Analiza economico-financiară a întreprinderii*, ediția a doua, Editura Economică, (2009).
- Peters, T.J., Waterman, R., *In Search of Excellence: Lessons from America's Best-Run Companies*, Harper Business Essential, (2006).
- Sousa, R., AVoss, C., *Quality management re-visited: a reflective review and agenda for future research*, Journal of Operations Management, Volume 20, Issue 1, pp. 91-109, (2002).  
<https://www.sciencedirect.com/science/article/abs/pii/S0272696301000882>

## The assessment of the quality of leadership as a resource for sustainable development

Vasile Robu<sup>a</sup>, Irina Daniela Cişmaşu<sup>a\*</sup>, Alma Maria Petcu<sup>a</sup>

*<sup>a</sup>The Bucharest University of Economic Studies, Bucharest, Romania*

---

### Abstract

The constraints of sustainable development in an environment marked by high dynamics of the volume, diversity, and magnitude of the changes with a particularly high degree of risk have led to the reorientation of management research towards an inexhaustible cardinal resource: human creativity. The purpose of this research is to highlight the importance of leadership in creating the vision and the team able to implement it, in converting the potential of each member into creative efficiency, in the stimulating synergy of the people to achieve excellence in business and ensure sustainable business development. Also, the main differences between leadership and management, as well as the fundamental qualities that define the leader have been identified. The quantitative research has led to identify on the selected sample the differences in the perception of leadership quality on three dimensions considered relevant: focus on the client, focus on the team, and focus on the results.

*Keywords:* sustainability; quality; management; leadership

---

### 1. Introduction

Globalization has created conditions for business location in the most cost-effective environments, but also for the proliferation of large corporations with rigorous management, structures and procedures based on a permanent process of research and improve in the field, in an extensive development process. Reducing growth rates, falling labor productivity, environmental imbalances in the economic and social sphere, increasing the cost of resources and internal holistic of these areas imply major challenges that exceed the possibilities of adapting of a management that remains in the limits of conformism of some procedures even scientifically elaborated and routine.

The research undertaken at the level of many companies has revealed that the sustainable development of an entity is determined by the quality of its management. At present, businesses that are looking for sustainable development are pursuing excellence in business. Management research has led to the development of business excellence models: the Australian Business Excellence Framework, the Malcolm Baldrige National Quality Award (MBNQA), the Canadian Business Excellence Model, the **European Foundation for Quality Management, and the Japan Quality Award**. One of the determinants of business excellence, common to all models, is leadership. After extensive research on company, J.Collins states that "Excellency is not circumstantial", that the strategy itself, no matter how well defined, as technology or technology change or compensation systems, top-class membership or scouting famous managers, etc. did not mark the difference between "good" and "excellent" and that the most important lever to reach this level is "fit people" and "level 5 leaders".

In the literature, we find numerous definitions of leadership:

„A leader is one who knows the way, goes the way, and shows the way.” by John Maxwell.

"Leadership is lifting a person's vision to high sights, the raising of a person's performance to a higher standard, the building of a personality beyond its normal limitations." by Peter F. Drucker.

"Innovation distinguishes between a leader and a follower." by Steve Jobs, 2013.

"True leadership lies in guiding others to success-in ensuring that everyone is performing at their best, doing the work they are pledged to do and doing it well." by Bill Owens.

---

\* Corresponding author. E-mail address: irina.cismasu@cig.ase.ro

In this context, the authors believe that the leader is the one who has a coherent vision of business and results, is able to assess the necessary resources, the stages of its realization and to create the team that adheres creatively and performant to this vision.

Leaders and their appropriate teams that address change and issues as opportunities and challenges for new approaches, new solutions, those who open up new perspectives and convert risk and danger into development and efficiency vectors, those who ensure the creative, innovative use of human potential, are, in the current situation, a decisive factor of sustainable development.

## 2. Leadership and management

Changing the management paradigm by moving from setting objectives and controlling their approach to a complex approach that includes all stakeholders in a business as well as dynamically amplifying the changes in the environment in which the firm operates, in conditions of increased competition, have forced new directions in the research of management and essential reconfigurations in this system. The researches have highlighted the importance of creative, innovative involvement of leadership and team in the company's sustainable development. In this context, leadership has been defined as a component of management systems that provides sustained competitive advantage.

In defining the notion of leadership, features that differentiate between the leader and the manager are distinguished some of the following:

leader	manager
Ability to develop and communicate visions, inspiring employees	Ability to build structures, to delegate authorities and responsibilities
Ability to change	Ability to lead
Ability to challenge	Ability to create rules, standards
Focus on understanding and interpretation, team building, motivation and influence of employees	Focus on planning, organization, control
Exercising authority through vision and ability to find solutions	Exercising authority through the position in company
Leadership is art and science	Management is science
Evaluating team members through their potential and commitment to materialize the vision	Employee evaluation through professional training and work outcomes

The company's performance involves the interference of leadership and management, an over management as well as the absence of genuine leadership capping the creative potential that ensures sustainability.

## 3. The fundamental qualities of leadership

Introspection in the sphere of defining statements on leadership has facilitated the structuring of the main qualities needed by a leader, organized on the axis: has vision - has integrity, considering the ability to lead the team from the latent to the creatively effective, integrated with the others.

We briefly present the significance of these fundamental qualities identified:

- has vision - a leader must have a specific way of understanding the situation and the context, as well as interpreting things or phenomena, identifying, developing and exploiting opportunities, acting in an efficient way to achieve the goal. The ability to develop and execute a coherent vision, to project them in complete detail and to follow its step-by-step materialization, to the last man and to the last detail is essential for the leader;
- has the knowledge and skill that must be continuously developed by being permanently in touch with people who have skills and abilities in progress that they lead or with whom develop partnerships to produce goods/services that meet the expressed and latent needs of consumers. One of the leaders presented by J. Collins states that "I never ceased to try to become qualified for the job entrusted to me", which exemplifies the most suggestive need for permanent training and information in the field;
- is an example - leadership involves responsibility within a team, and it must be aware that it is considered as an example through the way of thinking, through innovative ideas, through proactive attitude, by way of action;
- is creative and finds solutions - a leader must be innovative and make the team always open to new, find solutions to overcome constraints, solve problems, exploit opportunities;

- cares about people - the leader must perceive himself as a member of the team and is dedicated to it. The diversity of individuals in a team, the different personality involving specific attitudes and motivations, must be understood and considered opportunities. Full team engagement, recognition of individuality, identifying what everyone likes and what one can do best, boosting self-confidence provide competitive advantages at the organization level. Leadership is not about the leader, but the people in the team;

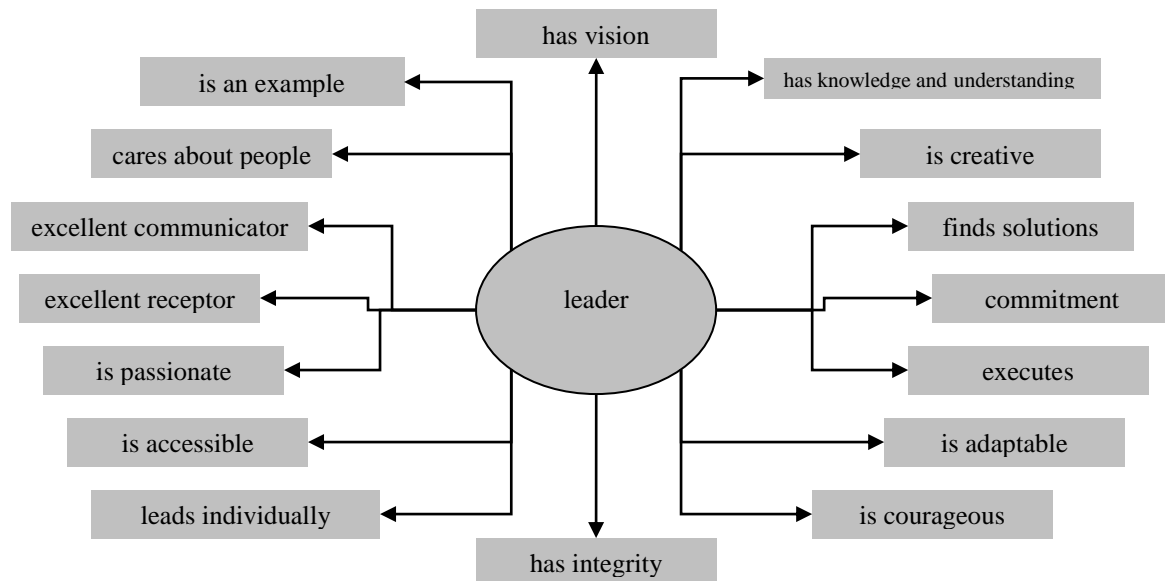


Fig.1 The fundamentals qualities of the leader

- is an excellent communicator and an excellent receiver - a leader must develop the ability to communicate clearly and concisely in the meaning of any person with whom they relate to in order not to create confusion and inaccuracies; at the same time, the leader must listen to any member of the team, partner, or other interested person, and to fully understand what is being communicated to make the most accurate decisions;
- leads individually - each member of the team is part of the joint effort, and the leader needs to know, guide and appreciate each person's work individually to make the most of their potential. The leadership translates the decision to the lowest level, considering as leader in its area of responsibility each member of the team;
- is accessible - resulting from communication and leading individually, accessibility becomes inherent, the quality of the messages and the time needed in the economy of the common project are to be appreciated in both directions;
- is passionate - leadership is art and science: for art you must have talent and passion without which you cannot have vision, you cannot act innovator, you cannot individualize yourself; for science you must always have up-graded knowledge, which again involves the passion and the constant interest in maintaining your right rhythm and preserving your quality of leader;
- engages himself and creates conditions for team members' engagement - engagement involves emotional involvement in creating value for the firm. In the context of assuming a common goal with the entire team, the leader must be proactive, point out the commitment of each member of the team or those who show inactive or even retroactive behavior. The art of engagement aims the decision regarding how to efficiently engage the team members. Commitment to the company goes to the preparation of equally visionary, passionate and involved successors. Precisely preparing such successors transforms a level 4 leader into a leader of level 5 and proves the involvement in the present and future company activity;
- executes - the leader has resources and must achieve results with maximum efficiency and effectiveness;
- is adaptable and courageous - an authentic leader needs to appreciate correctly what can change or when it is necessary to change himself and his team and have the courage to conform; an authentic leader views change as an opportunity for development and progress;
- his integrity - "The Supreme Quality of a Leader is Integrity" (Dwight D. Eisenhower); a leader assumes all decisions transmitted in their letter and spirit, does not admit ambiguity and inaccuracy.

The attachment to the company and its promotion to all team members accompanied by an extraordinary modesty and constant need to know all the aspects of the activities carried out, continually qualifying, but also the micro and the macro environment in order to adopt the most correct decisions, as well as the courage to accomplish them, regardless of difficulties, for the firm's sustainable orientation in the conditions of sustained growth of its performances are fundamental qualities of the leader at the top.

#### 4. The analysis of the quality of leadership - case study

In order to analyze the perception of the quality of leadership, a study based on the evaluation of three dimensions was carried out:

- focus on customer - validation of the company's efforts is carried out on the market by the clients. Leadership orientation towards customer satisfaction is a condition of ensuring sustainable development. The main criteria for assessing the quality of leadership in this dimension are: product/service innovation, value creation, flexibility, training and changing attitudes and needs, assurance quality throughout the product life cycle, elimination of deficiencies, and defects;
- focus on people: the leadership efficiency can be considered integrated to the performance of the team, as one of the fundamental features of leadership is the orientation towards the person as a potential creator of value. The main issues addressed are: personal development by turning potential into effectiveness, re-enforcing goals, ensuring a working climate that encourages and stimulates commitment and creativity, permanent and reiterating communication of the vision and ideas;
- focus on results: the quality of leadership is assessed by the company's results, targeting three levels of interest - customers (customer loyalty, increasing the attraction rate of new customers, increasing market share, increasing turnover), employees (reduction of staff fluctuation rate, increase in productivity, negative correlation index) and investors (profit, stock exchange rate, capital investment liquidity, return on investment)

#### Data research and analysis instrument

Quantitative research to assess the quality of leadership is based on a survey of leaders and employees from 11 hotel units, based on a questionnaire structured on the three dimensions considered, containing a total of 21 questions, using a Likert scale with 5 steps. Depending on the specific nature of the work done by each employee and the considered dimension, 18 leaders and a different number of employees expressed their opinion: 290 employees, for the assessment of customer focus, 375 employees, in the case of assessment of the team focus and 22 employees in the case of assessment of the focus on the result. Data analysis was performed using statistical methods, using the Excel software, the Data Analysis module.

Dimension	level	average	standard deviation	minimum level	maximum level
focus on	leadership	22,56	2,21	13	25
customer	employee	18,43	2,98	14	23
focus on person	leadership	15,5	2,3	8	18
	employee	13,25	2,31	9	16
focus on results	leadership	38,89	3,41	16	49
	employee	38.23	3,92	22	45

From the analysis we find a difference in the perception of the quality of the leadership at the level of the considered sample. For all three dimensions, there is an overestimation of the leader level compared to employees' one. The differences between the minimum possible level and the effective minimum are superior to those between the maximum possible level and the effective maximum, which reflects a superior qualitative level of leadership. At the level of each dimension, the difference between the leader's and employee's evaluation, based on the average, shows different values: 4.13 for focus on the team, which highlights reservations in the relationship between leader and team; 2.25 for focus on the customer, due to a relative similar appreciation of this dimension and 0.66 for the focus on the result that involves concrete quantitative assessments, limiting the differences in perception in relation to the assumed objectives. There are close values of standard deviations of leaders and employees at each level, which reveals a relatively similar appreciation.

## Conclusion

The complex of factors influencing the activity of an enterprise requires management to be at a higher level that transcends the rigorous scientific framework but relatively limited of the current approach in the field. It recognizes the need for leadership, leadership as art, visionary, and ability to adapt and solve correlatively the environmental challenges within an appropriate team that can transform constraint into opportunity and weakness in strength.

Leadership is equally visionary, creative, innovative lead, with firmness and determination, but also the ability to select and form a team where each member is a specialist, a leader in his area of responsibility. The ability to connect convergently and synergistically the creativity and effects of leaders at all levels is defining for leadership.

At the same time, leadership implies a deep attachment to the company for whose sustainable development his efforts are devoted in a permanent process of adaptive qualification to environmental change and conversion into the efficiency and effectiveness that the entire team makes. By affirming the leadership's supremacy, this leadership also affirms the essential role of the team in which each member is the leader in the assumed issues, under conditions of maximum responsibility.

## References

- Agle, B. R., Mitchell, R. K., Sonnenfeld, J. A., *Who matters to CEOs? An investigation of stakeholder attributes and salience, corporate performance, and CEO values*, *Academy of Management Journal*, volum (42), pp. 507-525, (1999).
- Alimo-Metcalfe, B., Alban-Metcalfe, J., *Leadership: Time for a New Direction?*, *Sage Journals – Leadership*, Volume 1 issue: 1, pp. 51-71, (2005).
- Avolio, B.J., Gardner, W.L., *Authentic leadership development: Getting to the root of positive forms of leadership*, *The Leadership Quarterly*, Volume 16, Issue 3, pp. 315-338, (2005).
- Bass, B.M., Steidlmeier, P., *Ethics, character, and authentic transformational leadership behaviour*, *The Leadership Quarterly*, Volume 10, Issue 2, pp. 181-217, (1999).
- Carroll, B., Levy, L., Richmond, D., *Leadership as Practice: Challenging the Competency Paradigm*, *Sage Journals – Leadership*, Volume: 4 issue: 4, pp. 363-379, (2008).
- Collins, J., *ExceleŃta în afaceri*, Editura Curtea Veche, Bucureşti, (2017).
- Drăgănescu, M., *InformaŃia materiei*, Editura Academiei Române, Bucureşti, (1990).
- Dulcan, D.C., *InteligenŃa materiei*, Editura EIKON, Cluj-Napoca, (2009).
- Graen, G.B., Uhl-Bien, M., *Relationship-based approach to leadership: Development of leader-member exchange (LMX) theory of leadership over 25 years: Applying a multi-level multi-domain perspective*, *The Leadership Quarterly*, Volume 6, Issue 2, pp. 219-247, (1995).
- Gronn, P., *Leadership Configurations*, *Sage Journals – Leadership*, Volume: 5 issue: 3, pp. 381-394, (2009).
- Groves, K.S., *Integrating leadership development and succession planning best practices*, *Journal of Management Development*, volume 26 issue 3, (2007).
- Grubor, G., Barac, I., Simeunović, N., Ristić, N., *Achieving Business Excellence by Optimizing Corporate Forensic Readiness*, *Amfiteatru Economic Journal*, Volume:19, pp. 197-214, (2017).
- Hernez-Broome, G., Hughes, Richard L., *Leadership Development: Past, Present, and Future*, *Human Resource Planning*, Vol. 27 Issue 1, pp. 24-32, (2004).
- Liden, R.C., Wayne S. J., Zhao, H., Henderson, D.J., *Servant leadership: Development of a multidimensional measure and multi-level assessment*, *The Leadership Quarterly* Volume 19, Issue 2, pp. 161-177, (2008).  
<https://www.sciencedirect.com/science/article/pii/S1048984308000040>
- Lowe, K.B., Galen Kroeck, K., Sivasubramaniam, N., *Effectiveness correlates of transformational and transactional leadership: A meta-analytic review of the mlq literature*, *The Leadership Quarterly*, Volume 7, Issue 3, pp. 385-425, (1996).
- Nicolescu O., *Sisteme, metode şi tehnici manageriale*, Editura Economică, Bucureşti, (2000).
- Pantea, M.I., *Analiza economico-financiară, instrument al managementului întreprinderii*, Editura Universităţii de Vest, Timişoara. (2017).
- Petcu, M.A., *Analiza economico-financiară a întreprinderii*, ediŃia a doua, Editura Economică, (2009).
- Raelin, J., *From leadership-as-practice to leaderful practice*, *Sage Journals – Leadership*, Volume: 7 issue: 2, pp. 195-211, (2011).
- Verma M.K., *Importance of leadership in total quality management*.

[https://www.researchgate.net/publication/295531927\\_IMPORTANCE\\_OF\\_LEADERSHIP\\_IN\\_TOTAL\\_QUALITY\\_MANAGEMENT](https://www.researchgate.net/publication/295531927_IMPORTANCE_OF_LEADERSHIP_IN_TOTAL_QUALITY_MANAGEMENT) [accessed Aug 25 2018].

Walumbwa, F.O., Avolio, B.J., Gardner W.I., Wernsing T.S., Peterson S.,J., *Authentic Leadership: Development and Validation of a Theory-Based Measure*, Journal of Management, October 26, (2007).

<https://doi.org/10.1177/0149206307308913>

[https://www.brainyquote.com/quotes/john\\_c\\_maxwell\\_383606](https://www.brainyquote.com/quotes/john_c_maxwell_383606)

[http://www.scielo.br/scielo.php?script=sci\\_arttext&pid=S1678-69712017000200104](http://www.scielo.br/scielo.php?script=sci_arttext&pid=S1678-69712017000200104)

<https://www.inc.com/peter-economy/44-inspiring-john-c-maxwell-quotes-that-will-take-you-to-leadership-success.html>

<https://www.forbes.com/consent/?toURL=https://www.forbes.com/sites/bwoo/2013/02/14/innovation-distinguishes-between-a-leader-and-a-follower/>

<https://www.qualtrics.com/blog/10-powerful-leadership-quotes/>

<https://www.inc.com/lolly-daskal/the-100-best-leadership-quotes-of-all-time.html>



# Increasing the Quality of the Taxes and Fees Impact Assessment on the Romanian Economy

Loredana Andreea Cristea<sup>a\*</sup>

*<sup>a</sup>Lucian Blaga University of Sibiu, B-dul Victoriei, no. 10, Sibiu, 550024, Romania*

---

## Abstract

The current market economy is characterized by a faster increase in resource requirements than the possibilities of obtaining them. Thus, it is crucial that any state address the problem in the most effective way, so that there is a balance between demand and supply (resources). The impact of taxes and fees on the development of the economy can be seen from the perspective of state incentives for investment and available financial resources. The two are in a relationship of dependence, saying that the lack of increase in the number of investments is a consequence of the additional tax, even with the aim of increasing the financial resources, but which still has daunting effects. In this context, this paper has as goal to set the basis for the development of a rigorous scientific research methodology aiming to bring more knowledge from the experience of developed countries in the researched field in order to identify proposals for streamlining the system of national taxes and fees, as well as adopting new methods and techniques for managing this complex system.

*Keywords:* quality; tax; fee; impact assessment; research methodology, finances, economy.

---

## 1. Introduction

Most of the state's financial resources are subject to mandatory levies, namely taxes and duties, which are income-generating sources and have a major impact on the functioning of the economy as a whole, in particular on the redistribution of economic resources. The tax and fees system is the main source of state budgeting, a budget without which the existence of a state is unthinkable. And depending on these additions to the state budget, it depends on the standard of living of all citizens, which materializes in the current state economy.

The actuality of the studied topic is conditioned by the need to estimate the impact and role of taxes on the formation of budgetary revenues, but also on the economy. Taxes have a decisive impact on the development of the national economy as they can be used as levers of economic and financial policy. In relation to the way the tax system is conducted within a state, it stimulates or inhibits the interest of citizens in carrying out economic activity, in consuming certain goods and / or services, but also in the commercial relations with the foreign partners.

It is also very important to ensure fiscal equity, which is only achieved when the tax burden is set and conditioned in proportion to the contributor's ability to pay. For example, if taxes are not too high and are optimal to be paid by all economic agents, an economy with fair competition unfolds, without appealing to tax evasion, and thus there is an interest in doing economic activity, resulting in the increase in payments to the state budget. An important effect of taxation is that it can affect a country's economic growth rate by deterring investors from investing in a country with strict tax rules.

## 2. Literature review

Concerns about the efficiency and optimization of the tax and fees system, both at national and international level, have generated numerous economic and financial studies, which have tried to provide solutions and models of action on the fiscal policy of states, having in view of the economic transformations over time (Cristea, 2017). The interests of

---

\* Corresponding author. Tel.: 00 40 720 399 245.  
E-mail address: crs.loredana@yahoo.com.

economists in the field of obtaining and use of public resources derived from the collection of taxes and duties have resulted in a significant number of papers that have addressed this issue.

The state of knowledge in this field highlights a significant number of papers addressing the efficiency, effectiveness and performance of the formation and use of public financial resources from taxes and fees, and for a more detailed analysis of this system are relevant the studies of Afonso (2008), Belean and Anghelache (2005), Brezeanu (2009), Dascălu (2006), Dobrotă et al. (2003), Drigă et al (2016), Moraru et al. (2011), Moşteanu (2008), Ungureanu (2010, 2013) .

Engen and Skinner (1992) pay increased attention to the relationship between the level of taxation and the rate of growth of gross domestic product, by increasing tax revenues and consolidating them at national level. Braşoveanu-Obreja (2007) outlines the relationship between taxes and the economy and observes that in practice, tax cuts have a positive but weak impact on a growing economy, thus leading to a change in long-term living standards. Arnold et al.(2011) concluded that a change that shows the biggest promise among taxes, both in terms of economic growth and economic recovery, is to reduce income taxes (including social security contributions) on those with low incomes. Kayaga (2007) concluded that the introduction of tax exemptions and deductions for essential goods and services benefiting the low-income population would not only bring tax benefits and other benefits to those with low incomes but would allow the government to offer some potential taxpayers who have hidden in the underground economy join the official economy.

Macek (2011) assessed the impact of different types of taxes on economic growth by conducting a regression analysis in OECD countries for the period 2000-2011, concluding that OECD countries should seek to reduce the corporate tax rate, taxes on personal income and social security contributions in order to be able to influence the economy in a positive way. Costi et al. (2004) argues that taxation can play an important role in improving the current situation and in ensuring a favorable environment for economic activities. Two different methods can be used, both with reference to how fiscal pressure is managed. Thus, it can appeal to a high fiscal pressure where the state builds a significant part of the gross domestic product at its disposal, thus limiting the financial resources that people can have. The second possibility is expressed by a reduced fiscal pressure. This has the effect of obtaining more financial resources from the population, and the state will collect a small part of the gross domestic product.

Mahdavi (2008), Castro et al. (2014); Bujang et al. (2013) and Stoilova (2017) are among the authors who studied the fiscal pressure of the tax and fees system and made comparisons in several developed and developing countries. They also attempted to show the connection between the fiscal pressure and the change in the economic indicators of the studied field.

Regarding tax evasion which is closely linked to the tax and fees system, Sabaini and Jimenez (2012) concluded that the benefits of improving tax administration can only be achieved under a number of conditions such as: a political commitment to the implemented reforms, the desire to abandon the old administrative practices and the desire to establish a formal plan with defined goals and costs for realistic time periods. They argued that only by establishing a high level of tax compliance will it be possible to implement reforms that involve the balance between direct and indirect taxes and thus, with regard to tax systems, to focus not only on the revenue target, but also on the objectives of efficiency and distributive equity so that tax evasion is at minimum levels.

### 3. Prerequisites for methodology development

The specialized foreign literature offers us limited scientific data, becoming restrictive due to the advanced degree of change in the field of research, without deepening and building up the economic dynamism through the system of taxes and fees. Given that this scientific research focuses on the close relationship between two disciplines with a strong influence on a state, *public finances*, namely the tax and fees system, and the *economy*, it is necessary to have a good knowledge of the specialists' concerns related to the improvement of these areas for the rational use of financial resources from mandatory levies, which have a positive impact on the economy.

The existing gaps between Romania and the developed countries in the world in general, and the EU states in particular, are mainly due to the lack of ongoing state reforms as well as medium and long-term strategies and programs in all fields, which make it necessary to study some possibilities increasing the efficiency of the system of taxes and fees, but also understanding its influence on the Romanian economy. The research theme involves tackling a very complex issue with many interdependencies, between mandatory tax deductions and the national economy.

In Romania's financial and economic research practice, scientific studies have been carried out on some aspects related to this research topic. However, these are not integral studies to address the issue of the tax and fees system and its impact on the national economy, in the light of several interdependent elements such as fiscal pressure, tax evasion, but also economic indicators which could highlight the close link with the main financial levers under market economy conditions. Taking into account this context, the hypotheses behind this research methodology are including:

- identifying proposals for streamlining the tax and fees system in Romania, possible by consulting and following the experiences of developed countries in Europe
- tax evasion, which is a barrier to a growing economy, can be diminished by adapting new techniques or methods of managing this complex system;
- the existence of a significant correlation between the tax and tax system and the economic impact indicators.

The **main purpose of the methodology** will be to identify ways to increase the efficiency of tax and fees system management by assessing the impact it can have on the economy, capitalizing on the experience of developed countries in Europe. In order to achieve the initial aim proposed in this research, the methodology will have to address the following **main objectives**:

### 3.1. Theoretical foundation of the tax and fees system

In order to have a basis for starting the research, the theoretical approach to the concept of fiscal system will be discussed, emphasizing the functions and role of its components, namely: *fiscal legislation*, which directly refers to the topic of this research theme, namely taxes and fees; *fiscal mechanism*, which means the techniques and procedures for organizing and managing the activity of tracking and collecting taxes and fees; and the *tax apparatus* respectively the institutions and the staff who act for the purpose of calculating, tracking and collecting taxes and fees. In order to highlight the opportunities for capitalizing the influence of the tax and fees system on the economy, a first step is to study the concept of a system of taxes and fees, how to organize it, but also to present it by emphasizing the features and functions detained.

Given that *taxes and fees* are components of tax revenues and are means and levers for budget revenue generation, a theoretical and conceptual approach is needed to understand how they are formed, the main features, and how effective management of these should occur, so as to reach a level of growth and socio-economic development. To conduct research on *budget revenues*, we need to know their content, structure and characteristics in order to be able to outline their complex effects on the economy. Of course, it is also necessary to conceptualize the taxes and fees by emphasizing their fiscal principles and their importance as financial levers and a means of stimulating the economy.

On the basis of the reports of the Ministry of Finance, as well as other data available from official sources, a study on the evolution of budgetary revenues will be carried out, focusing on Romania's tax revenues compared to EU Member States during the 2007 - 2018. Determining the place held by Romania within the European Union will be the starting point for the next comparative studies.

### 3.2. Influence on the economy framework of the tax and fees system, in European context

The conceptual delimitation of the *market economy* and the desiderata of *economic development* are necessary to outline the impact of taxes and fees on the economy, given that the market economy is the place where entrepreneurs operate freely, autonomously and rationally, in line with market requirements, to meet ever-increasing needs with limited economic resources. In order to give an overview of the fiscal pressure in the European tax system, a comparative study of Romania with the economically-financially developed countries and with the emerging countries will be carried out.

From the point of view of the impact of taxes and taxes on the economy, a correlation will be made between the level of income tax, profit, VAT level, excise level and customs duties and their influence on prices, demand for goods and services. A negative result of the high fiscal pressure is tax evasion, which can be considered a barrier to long-term economic growth. Tax evasion arises as a result of deficiencies in legislation and, on the other hand, due to the misapplication of tax evasion laws. An effect of tax evasion is the decrease in tax revenue collected, which leads to an increase in the budget deficit, having an effect on the overall balance of the economy.

### 3.3. Rational tax revenue management to improve and ensure a balanced economy

The fiscal policy promoted by the Government influences the formation of tax revenues, and the state can thus intervene through taxes in the way it desires by granting tax incentives to encourage and stimulate investments, by which to achieve export and import systematization, but also a tool to reduce inflation. In order to analyze and highlight the state intervention on the economy through the tax and fees system, a comparative study between Romania and Bulgaria will be carried out, assuming that both countries have joined the European Union in 2007. The analysis period will include both pre - accession and post - accession, up to date, according to the data available in the Ministries of Finance reports in both countries, as well as other official sources.

In analyzing the comparative situation between Romania and Bulgaria, it will be necessary to *characterize the tax and fees systems*, to highlight their structure in the two countries, by shaping the fiscal policy regarding the direct and indirect taxes. As tax revenues contribute significantly to the formation of the state budget, their modification would determine both positive and negative influences on the socio-economic situation in the country. Therefore, it will be necessary to highlight and outline an effective way of managing tax revenues, in order to ensure a growing economy.

### 3.4. Influence of the tax and fees system on the Romanian economy. Capitalization opportunities

Assessing a correlation between the main indicators with an effect on the economy (gross domestic product, inflation, unemployment rate, employment rate, public debt, income distribution, gross average earnings, etc.) and taxes

in Romania over the proposed period to be analyzed, respectively the last 20 years, will allow to highlight the influence of the fiscal revenues on the Romanian economy. Tax evasion, corruption, accession to the European Union and the economic and financial crisis that our country get over, have left deep fingerprints in the Romanian economy. Correlations should be made between all these aspects, using the SPSS statistical program, using mathematical modeling, but also by analyzing the resulting data and graphics.

To deepen the study, by means of the questionnaire addressed to the Romanian taxpayer, both to natural persons and legal persons will emphasize the perception of the need to pay the taxes and fees in order to determine the main causes of avoidance from their payment. The results obtained will highlight the importance of fiscal rules in *developing an effective tax and fees management methodology* to reduce tax evasion and economic growth.

It will be analyzed the situation of Romania by focusing the research direction on the main objectives of the Government regarding: the effective collection and use of mandatory levies - taxes and fees; how to implement the tax and fees system and how to manage them efficiently.

Examples of good practices in European countries can be milestones and starting points in developing ways to capitalize on the impact of the tax and fees system on the Romanian economy. In the context of these clarifications, the *main fiscal measures adopted by Romanian authorities* to support economic development will be identified to *develop tax policy recommendations* so that tax and fees collection can be efficiently achieved, to sustain economic growth and make tax evasion more difficult.

#### 4. Developing the research methodology

The research methodology expresses a combination of methods to facilitate the understanding of the purpose of research and the interpretation of the results. There will be combined *theoretical research*, which will delineate the conceptual aspects of the tax and fees system, fiscal policies, budget revenue structure, with *empirical research* to analyze financial and non-financial elements directly related to the subject under investigation.

The methodology will have an interdisciplinary character, covering aspects that are found in the economy, public finances, economic-financial analysis, statistics and legislation. In order to achieve the objectives, the aspects will be treated in a deductive approach, from general to particular, combining quantitative and qualitative elements. Research methodology requires the use of various tools, techniques and methods, given the complexity and interdisciplinary character of processes. Combined and complementary use of qualitative and quantitative methods will be applied.

*Quantitative approaches* are based on the numerical measurement of some aspects specific to the phenomenon studied, with the aim of testing the hypotheses, and the *qualitative research* follows the comprehensive description of the phenomenon. Quantitative approaches allow the formulation of assumptions about a large number of variables with a higher validity.

The methodology will have to include:

- *Studying the general bibliography* (economics, public administration, legislation) and specialty literature (finance), respectively on national and international level, as well as EU reports, domestic and international governmental sources, as well as from the non-governmental sector and international financial institutions, for the scientific substantiation of further research;
- *Method of scientific observation* of the activity of formation and use of taxes and fees, by performing comparative analyzes on the situation existing in the E.U. and Romania, from the perspective of the influence on the economy and from the perspective of the system of taxes and fees as *a target group*;
- *Explanatory research method*, which seeks to find out the underlying causes of a particular thing by establishing a causal relationship;
- *Method of analysis and synthesis, induction and deduction* by which theories are verified, generating results that can be generalized, the *analogy*;
- *Interdisciplinary methods* for correlating economic, financial and legislative concepts;
- *Statistical methods* used to interpret the results obtained in empirical research, data analysis that can be performed using the SPSS (Statistical Package for Social Sciences) program, allowing the statistical analyzes required for the research work;
- *Case study* for a thorough and in-depth investigation of the implications of the tax and tax system.

The data collection techniques to be used are:

- Documentation will be an important step in the process of knowing the studied topic (legislation, guides, strategies, plans);
- Reports, studies, and syntheses on the subject of the study;
- Structured questionnaires;
- Official statistics.

With the help of the questionnaire, information will also be collected on the Romanian taxpayer's perception of the necessity to make mandatory payments and the determination of the main causes of payment forgery. Then, it will be correlated these perceptions with the results of the main indicators of influence on the economy and the study of the existing impact. Data analysis will use the SPSS statistical program.

The results of the research will be interpreted and presented in the form of conclusions that will come to bring added insight into the investigated field and may be the starting point for further research. As an expected scientific result of the future methodology, we aim at obtaining the Romanian taxpayer's perception of the necessity to make these mandatory payments and the determination of the main causes of payment forgiveness. It is also targeted the correlation of these perceptions with the main indicators of influence on the economy and the study of the existing impact.

Determining the impact of the tax and fees system on the economy, entails a number of advantages that are highlighted below:

- identifying the main financial elements that influence the Romanian economy;
- the possibility of developing a new way of implementing and designing the tax and fees system, taking into account good international practices where the impact on the economy is positive;
- relieving the importance of tax rules in maintaining / growing economic development through taxes and fees;
- finding ways to improve the tax and fees system by making comprehensive comparative analyzes of tax policies in developed EU countries as well as in neighboring countries to Romania and similar in terms of development;
- highlighting solutions to optimize the tax and fees system in Romania by making a comparison of the fiscal pressure at the level of the countries of the European Union, taking into account the structure of the tax revenues;
- developing effective tax management methodologies to reduce tax evasion;
- drawing conclusions on the correlation between the tax and tax system and the main indicators influencing the economy;
- Streamlining the fiscal revenues management with a view to improving and ensuring a balanced economy, also taking into account the perceptions of the Romanian taxpayer;
- Making proposals on simplifying the mode of charging taxes in order to relax the taxpayer.

All these advantages, derived from the proposed research, can lead to a set of recommendations and procedures that will help to increase the performance of tax collection so as to obtain a positive impact on the Romanian economy.

## 5. Discussion and conclusion

Given that tax revenue holds an important place in forming a state's public revenue, its importance is understandable. In order to have a well-established starting point for research, a unitary analysis of the components of the tax system, the way it is formed, and the functioning of the financial mechanism is needed. *Taxes and fees* have a complex role within any state, being a pillar that influences the economy, and therefore, through this research, we are aiming to study this in depth, since the system of taxes and fees is not limited to procurement and distribution of public financial resources.

Decision-makers can and should direct this system towards economic and social development of the country, and an important concern of the future methodology will be to find *opportunities to capitalize on the influence of the tax and tax system on the economy*. Tax revenues, namely taxes and fees, are influenced by the *fiscal policy* adopted and promoted by the government, but there are also economic factors that act on them. These factors of economic nature that determine the evolution of tax revenues can be represented by indicators such as: gross domestic product, inflation rate, public debt, population, income distribution, gross average earning, employment rate, but also the form of taxation of entities and facilities granted to them.

Account should also be taken of the *influence of taxes on the economic activity* of enterprises in general, as indirect changes may take place within the national economic structure. Thus, microeconomic taxes can play a role of development, contributing to job creation, balancing import and export operations, leading to inflation and unemployment cuts, but can also play a negative role, which discourages economic behavior. However, this depends on the tax rate and the economic agent's elasticity to tax. Through this research, we would like to emphasize these possible influences, to discover the correlations between the economy and the fiscal system, but also beneficial possibilities of its management, towards the creation of a positive economy.

Another concern of this research is the study of *tax pressure*. That is why, in order to deepen this element, we will use the study of the fiscal pressure at the level of Romania, but also at the level of the European states. This analysis, which should be drawn up in comparison with the fiscal pressure at the level of the developed EU countries, aims at deducing optimal solutions or ways of rationalizing fiscal revenues, which can be adopted through fiscal policies, so that fiscal pressure is at an affordable level for citizens.

Referring to previous research focusing mainly on the structure and weight of the tax and fees system within consolidated general budgets, and to the adequacy of these studies with the socio-economic environment, the relevance of the scientific outcomes of this research appears as a natural consequence of the fact that it is necessary to know and operate in order to make the impact of the system of taxes and duties on the economy more efficient, in the context of Romania, as an EU member state.

## References

- Afonso, A., Schuknecht, L., Tanzi, V., *Income Distribution Determinants and Public Spending Efficiency*, ECB Working Paper no. 861, (2008).
- Arnold, J., Brys B., Heady C., Johansson A., Schwellnus C., Vartia L., *Tax policy for economic recovery and growth*, The Economic Journal, 121, (2011).
- Belean, P., Anghelache, G., *Finanțele publice ale României*, Ediția a II-a, Editura Economică, București, (2005).
- Brașoveanu-Obreja, L., *Impactul politici fiscale asupra creșterii economice*, Editura ASE București, (2007).
- Brezeanu, P., *Fiscalitate - Concepte, teorii, politici și abordări practice*, Editura Wolters Kluwer, București, (2009).
- Bujang, I., et. al., *Tax Structure and Economic Indicators in Developing and High-income OECD Countries: Panel Cointegration Analysis*, Procedia Economics and Finance, Volume 7, pp. 164-173, (2013).
- Castro, G., A., Camarillo, D., B., *Determinants of tax revenue in OECD countries over the period 2001–2011*, Contaduría y Administración, Volume 59, Issue 3, pp. 35-59, (2014).
- Costi, B., Boiță, M., Remeș, E., *The Impact Of Fiscal Pressure In The Contemporary Economy*, Economy And Management, Communication, Context, Interdisciplinarity - 3rd Edition, ISSN: 2069 – 3389, Universitatea ”Petru Maior” din Târgu Mureș, 2004
- Cristea, L., A., *The share and evolution of indirect taxes in state revenues - the case of Romania*, Annals of the University of Petroșani, Economics, vol 17 (1), (2017).
- Dascălu, E., D., *Sistemul bugetar în România*. Editura Didactică și Pedagogică, (2006).
- Dobrotă, G., Popeangă, G., Paliu Popa, L., *Sistemul fiscal în România*, Editura Spirit Românesc, (2003).
- Drigă, I., Dura, C., Cristea, L., *The Impact of the Financial Crisis on Bank Profitability*, Annals of the University of Petroșani, Economics, vol.16(2), (2016).
- Engen, E., M., Skinner, J., *Fiscal Policy and Economic Growth*, NTJ, Vol. 50, no. 4, pp. 617- 642, (1997).
- Gomez Sabaini, J., C., Jimenez J., P., *Tax structure and tax evasion*, Economic Development Division, United Nation Publication, Santiago, (2012).
- Kayaga, L., *Tax policy challenges facing developing countries: a case study of Uganda*, Ph.D. Thesis, Queen’s University Kingston, Ontario, Canada, September, , Available at: <https://www.collectionscanada.gc.ca/obj/s4/f2/dsk3/OKQ/TC-OKQ-850.pdf>, (2007).
- Macek, R., *The Impact of Taxation on Economic Growth: Case Study of OECD Countries*, Review Of Economic Perspectives Vol. 14, Issue 4, pp. 309–328, (2014).
- Mahdavi, S., *The level and composition of tax revenue in developing countries: Evidence from unbalanced panel data*, International Review of Economics & Finance, Elsevier, (2008).
- Moraru, R., I., Băbuț, G., B., Cioca, L., I., *Drawbacks and traps in risk assessment: examples in Romania*, Proceedings of the 5th International Conference on Manufacturing Science and Educations - MSE 2011, Volume II, pp. 363-366, Sibiu, Romania, 02-05.06.(2011).
- Moșteanu, T., *Finanțe publice*, Editura Universitară, București, (2008).
- Stoilova, D., *Tax structure and economic growth: Evidence from the European Union*, Contaduría y Administración, Volume 62, Issue 3, pp. 1041-1057, (2017).
- Ungureanu, M., A., *Controlul fiscal și evaziunea fiscală*, Editura „Conphys”, (2010).
- Ungureanu, M., A., *Politici și Practici Financiare*, Editura Universitară, București, (2013).

## The Institutional Relations Between State Powers

Adelin Ungureanu<sup>a\*</sup>, Oana Răvaș<sup>a</sup>

<sup>a</sup>University of Petroșani, Str. Universității nr. 20, 332006, Petroșani, Romania

---

### Abstract

At central level between main country's institutions are established different relationships about exercising of powers and performing the tasks at each level of any central institution or in case of exercising of a special leverage, depending on constitutional provisions. Broadly, are envisaged reports of institutional between Parliament and Government, between Parliament and Judicial Authority, between Government and Judicial Authority, but also President's reports and tasks with each of three powers. Despite we take into consideration the division of power, according to the theory of their division, established in the supreme law, these are the powers of the same state, and for his uniform operation, as well as several another reasons, between the three powers certain operating mechanisms are created, and the President, in turn will exercise constitutional role of guarantor and mediator, developing different relationships with each power.

**Keywords:** President; Parliament; Government; The Theory of the separation of powers; Supreme Council of Magistrates; Constitution of Romania.

---

The theory that discusses the separation of powers received acknowledgement in recent years and was introduced in a lot of fundamental laws, in different countries around the world. It may be the case that is not the perfect mechanism for the organization and functioning of a state, but until now this system proved to be a democratic and efficient one, accepted and approved by citizens around the world. It represents a good way for the organization of a state, that respects the democratic values and principles, and even if it involves a certain separation (the separation of powers), the state remains a solid and unitary one.

The Romanian Fundamental Law acknowledged this principle, even from its early beginnings. Consequently, the state *“is organized according to the principle of separation and balance of powers – legislative, executive and judicial – in a constitutional democracy”* (Romanian Constitution, art.1, paragraph 4). The three powers are: the legislative power, the executive power and the judicial one, in the exact mentioned order, as it is stipulated in the Supreme Law' text.

These three powers are assigned as follows: the legislative power belongs to the Parliament *“The Parliament ... is the only legislative power of our country”* (Romanian Constitution, art.6, paragraph 1), the executive power belongs to the Government *“... that is responsible for implementing the internal and external policies and for assuring the general management of the public administration”* (Romanian Constitution, art. 102, paragraph1), and the judicial power which belongs to the judicial courts *“Justice is assured through the Supreme Court and through other courts that are established according to law”* (Romanian Constitution, art. 126, paragraph1). Some argue that the President also has one of the three powers, namely the executive power, of course, alongside the Government. In order to better understand this last statement, I go back to the fundamental law: *“...the President plays his role as mediator between state powers, as well as between state and society”* (Romanian Constitution, art. 80, paragraph 2). Considering this, the president would be unable to play his role as mediator between state powers, as long as he is part of one of these powers, namely the executive one. It's true that through his/her responsibilities, the President has some competences that are in line with state powers. Among these, one can mention for instance, in the case of the legislative power, the fact that the President takes oath in front of the Parliament and has the power to dissolve it, in certain conditions. In the same time, in case of vacancy of the presidential power, the interim is assured by a member of the Parliament, either the President of the Senate or the president of the Chamber of Deputies. In terms of the Executive power, the president assigns the person that could become the prime minister, as long as the person proposed, together with his/her team, obtains the majority vote in the Parliament. In addition, the President is able to revoke the ministers if the prime minister proposes so, and

---

\* Adelin Ungureanu. Tel.: +400742005960;  
E-mail address: adelin13ungureanu@yahoo.com.



can attend the Government's meetings. In terms of the judicial power, the President appoints and revokes magistrates, after a proposal that comes from the Supreme Court of Magistrates. Considering all these, one can conclude that the President has an active role in some aspects related to the three state powers, not only in terms of the executive one. In addition, the fact that he is responsible for mediating among these powers, excludes the possibility for the presidential power to be a specific one for only one power (namely the executive), as long as the president needs to play an equidistant role towards the other three powers. In conclusion, the President: represents the Romanian state, is a guarantee for certain values and principles (Independence, unity, territorial integrity), and watches over the compliance with the Fundamental Law, mediates among the state powers and is the Supreme Commander of the army forces (Muraru, Tănăsescu, 2016, p.261).

The acts issued by various institutions or authorities could be contested within an administrative appeal procedure, being subjected to legal control. Still, some sorts of relations, as the institutional relation between the Parliament and other public authorities are exempted from this type of control (Manta et al, 2014, p.242), in order to not block the activity of one of the main state institutions, as is the Parliament.

Even though we talk about the separation of powers and a President that mediates among them, they are all part of the same state, organizing and assuring the function of the state. Consequently, the three powers, even if they are separated, they all function in a unitary national system. The cheques and balances among them is assured through all sort of institutional relations that are regulated by normative acts and following a legal basis.

Certainly, the institutional relations are regulated through the existing legislation. Even though we cannot argue against these types of institutional reports, it was with the same reason of regulating the relations between people that the most ancient laws of humankind were written: the Laws of Mu in China, Ennuna Code in Mesopotamia, four thousands of years ago (Mihai, 2004, p.31). In addition, in a similar manner as we know them today, these institutional relations were included in Roman law, or in other judicial systems, like the German or the Anglo-Saxon (Dănișor et al, 2008, p.129) ones we all agree that the written form of these regulations confer more stability and judicial force.

## **1. The institutional relations between the legislative and executive powers**

Firstly, one can talk about the institutional relations among two central institutions: the Parliament and the Government. Of course, the main types of institutional relations are at the level of these institutions, even though the entire public administration functions according with the normative acts adopted by the Parliament.

In addition, one can state that the Government exercises its power only after receiving the vote from the Parliament, following a procedure that includes also a decision from the President, before the final vote in the Parliament. Consequently, the structure of the Government, its members and the governing program receives a vote from the legislative power. The Parliament issues a substantive decision, in this case, without being forced by the Constitution to accept any proposal from the President for the future prime minister. The Parliament can either accept through a vote, as well as to reject the proposal. In case of a rejection, all the procedures, including that of the nomination from the President, are repeated.

In the same time, the Parliament can dismiss the Government through a vote, during its mandate. In this respect, it doesn't matter how much time passed since its nomination or how much time is left from its mandate. The legislative authority, through the adoption of a vote of non-confidence is able to dismiss the Government, if that is the wish. The non-confidence vote can be initiated by the members of Parliament and the Government has no possibility to intervene in this process. Actually, there are two types of procedures that enable the initiation and debate of a non-confidence vote. Consequently, during each session of the parliament, the members of the legislative body are able to initiate one non-confidence vote. Since the mandate of a member of Parliament includes 8 ordinary sessions, it means that the members of parliament, (especially the one in the opposition) during their mandate, can initiate 8 such votes that eventually can dismiss the Government. The other procedure can only be initiated by the Government. Therefore, it is usually initiated for fast decisions, or to avoid long lasting debates that can produce changes in the Government's proposals. In these situations, the Government can initiate the Government Accountability Procedure on a bill or a declaration. In this situation the Government chooses a quick way to pass laws. The Parliament can initiate a non-confidence vote, even if in that session there was another one already initiated. After the Government Accountability Procedure is initiated, in only 3 days, the Parliament can initiate a non-confidence vote and consequently dismiss the Government. If the non-confidence vote is not adopted by the Parliament, the Government continues its activity, since is considered that the Government still has the approval from the majority of Parliament, and the proposed bill, program or declaration are considered adopted. They enter into force only after all these procedures are finished.

The Parliament also has the power to ask the Government, or other institutions and authorities at local or national level, various information or other documents, due to the parliamentary control function that both of its chambers have. In addition, the Parliament can also organize special investigation committees, where the members of Parliament can ask for additional information, can hear different persons or collect documents that are issued by different bodies that are involved in public activities.

In the same logic related to the reports between the legislative and executive powers one can also mention the possibility of the members of Parliament to address questions or hecklings to all members of Government. These questions are addressed on different issues, and the members of Government, to which the questions were addressed,

are obliged to respond, according to the Parliament's regulations. Basically, this is a form of official informing, for every Member of Parliament, on various issues that are not necessarily related to the legislative activity but are related to topics that are related with their activity. Therefore, these questions are directly addressed to the ministers, based on the activity of the Ministry they are in charged with.

Another important aspect, related to the relation between the Parliament and the Government is related to the procedure for the delegation of the legislative power. As mentioned before, the Parliament is the only authority that passes laws. Still, through the institution of delegating the legislative powers, in some particular conditions, during specific periods of time, and with a very strict follow up and verification, this power is transferred to the Government. This special procedure for delegating the legislative power is done through two types of decrees: Government Decrees (OG) or Emergency Decrees (OUG). For the first category, the Parliament initiates a special law, for enabling the Government, in a limited period of time and in a certain field, to issue normative acts. In the same time, The Parliament could also ask that the OG be sent and confirmed by the Parliament, based on its statute, as unique authority for passing laws. The Parliament could also adopt, modify or reject the OG, even if this was already issued and even started to produce its effects.

Analyzing these aspects separately, one can easily say that there is a need for further discussion. In the case when the Parliament approves the OG, this is nothing else than a confirmation for the Government to continue its proposal. In the situation when the OG is modified, and it is not about some slight additions to the decree's original text, but it is about the rejection or the actual change of text, then we are in the situation where we have some judicial norms that already produce their effects without being approved and confirmed by the legislative authority. This situation is even more obvious in the case when the Parliament rejects entirely the government's decree. Consequently, the decree manages to produce some concrete judicial effects, similar to a law, even if it was issued through a different procedure, by the Government. This exception lies in the fact that we have judicial norms that are compulsory for the population, even though the Parliament never adopted them and is not adopting them, but basically decides on their later rejection. The reason for this possibility for delegating the legislative power, is that of the need for quick decisions, or when there is a need for decisions and the Parliament is in vacation. Still, starting from this, there are a lot of situations, at the borderline of this principle, when we have a lot of legislative acts that are implemented with clear effects without being approved by the Parliament, or with later rejection and elimination by the Parliament.

On the issue of Emergency Decrees, there is no need for a special delegation from the Parliament, but it needs to be used as a procedure in extreme situations in which the Government needs urgent legislative interventions. In these situations, the Government can pass laws but it is obliged to clearly indicate in the text the emergency that led to this legislative initiative. In addition, even in this type of decrees, following a certain procedure, and with very short deadlines, there is also a need for confirmation, modification or even rejection coming from the Parliament. These stipulations follow the same logic of the exclusive legislative competency that the Parliament has, even if there are some exceptions, in very specific conditions and circumstances.

## **2. The institutional relations between the executive and the legislative power**

In order to exemplify this category of relations, I focus mostly on the type of initiative that thrives these relations. In the sections of this paper that I discussed above I introduced only those institutional relations that are initiated by the legislative power (vote of confidence or non-confidence for the Government or the legislative delegation for issuing governmental decrees). In the following section the focus will be on the three types of relations that are initiated by the executive power, namely the governmental authority. Even the issuing of emergency governmental decrees is probably better included in this section, then the previous one. This is the case because there is no delegation needed from the Parliament. Still, for a better understanding of the procedure for legislative delegation, it was included in the section above, together with the simple governmental decrees.

The legislative initiative is a common and very important procedure in consolidating the legislative system. The Government has the power to initiate laws in terms of both organic and ordinary laws. This initiative implies a few stages, including the preparation of the law, which is later on transmitted to one of the chambers of the Parliament, based on their competences. The final stages are that of debate and approval. This right of legislative initiative that the government has, is widely used. Basically, it means that almost all current laws were initiated by the Government. Once the Parliament receives the law proposal, it is not obliged to adopt it in that exact form that was sent by the Government. It usually follows a series of procedures, through which the proposal is either changed (it can be changed even substantially) or it is discussed and debated in the exact form in which it was sent by the Government. Eventually the proposal is adopted with the agreed changes or rejected by the legislative power.

Even in this respect, if we take into consideration the principle of cheques and balances, the above described procedure is debatable. Since there is a legislative power, as unique authority in this respect, why do we need another state power to initiate laws? In addition, if we also consider the highest number of laws are introduced through this type of initiatives, compared to the ones initiated by the legislative power, then the debate is even more interesting.

We are talking about the powers within the same state and even if they are separated due to certain regulations, the fact that they collaborate or even control themselves sometimes (e.g.: the vote for dismissing the Government, through a government decree), it does not mean that this separation of powers is not respected. It is most likely that the delegation

of the legislative power that we already talked about, with the Governmental decrees being rejected by the Parliament, is situated at the limit of this principle of separation. It is actually due to practical reasons, that the Government received the right to initiate laws, since it is better connected to the socio-economic realities of the country and the surrounding ones. Still, the Parliament has the last word, respecting the fact that it is a representative institution, elected by citizens.

Even though, in this paper, I've already talked about the Government Accountability Procedure as a procedure for initiating a bill, declaration, or a certain program, by the Government, this procedure should also be included in this section. The decision to start this procedure belongs exclusively to the Government that actually forces the Parliament to pass laws for the Government. In addition, the Parliament, through the vote of no confidence, has the possibility to revoke the Government. At first sight, it is probably considered as a worthless risk coming from the governmental institution. Indeed, having the right to initiate laws, it is pointless to risk its position through the Government Accountability Procedure. Still, using this procedure assures the adoption of a law in a matter of days in the exact form that the Government wants, since the Parliament has no possibility to change it. In reality though, the risk that the Government takes is only an apparent one. It's true that there could be some situations, in which through the Government Accountability Procedure the Government could be dismissed, but both Parliament and Government have political structures at their basis. Moreover, since the Government receives the confidence vote from the Parliament, usually representing the same political party, the majority in the Parliament has no reason to dismiss its own government, so the chances for this to happen are almost inexistent. Still, if the Government uses this procedure vastly, one can conclude that it cancels the main function that the Parliament has, surpassing, in the same time, the values and principles of the separation of powers.

### **3. The institutional relations between the executive and the judicial powers**

As mentioned in the previous paragraphs, between these two powers there aren't many institutional relations, considering the judicial independence, as indicated before. When we talk about magistrates, we refer to the judges and the prosecutors. If in the case of judges, they are completely independent, based on the constitutional norms, the prosecutors are working, according to the constitutional norm, in a system of hierarchic control. This control manifests itself in a close loop, that of the State Attorney's offices, where no other power has access to the mechanisms for organising and functioning of its activity. Still, what leads to certain types of relations and reports is another constitutional norm, the one stating that *„the prosecutors are acting under the authority of the Minister of Justice”* (Romanian Constitution, art. 132), without having a clear explanation of what this function means. The opinions about this issue are different and vast. Some are arguing that starting from the idea that the prosecutors are a category of professionals that work under the principle of hierarchic control, this hierarchy goes directly to the minister in charge, namely the Minister of Justice. In the same time, others are arguing that it is only a matter of administrative control, which is consistent with the way the Public Minister is organized and functions, as it is stipulated in the supreme law.

Trying to analyse this from a strictly normative perspective, we take into consideration the terminology used in the Constitution, in chapter VI. Consequently, when using the term authority, this is used to describe the system – the judicial authority – but also to describe the activity of prosecutors – under the authority of the Minister of Justice. The fact that the judicial system represents a power and an authority in itself is unquestionable. Still, whether the authority of the Minister in relation to a category of magistrates, and whether this implies functional and professional functions or purely administrative, is a good topic for debate.

Continuing the same discussion on the relation between the judicial and executive powers, one needs to mention also the fact that a separate institution is in charged with the guarantee for the independence of Justice - The Supreme Council of Magistrates (CSM). This institution has 19 members, and one of the members is the Minister of Justice, therefore a member of the executive power. Even though we have the situation described above, this institution is not acting like a court, in the sense of running investigations or solving disputes, its responsibilities are more related to the management of Justice, or other aspects that are related to the constitutional guarantees of Justice.

Despite the relations that were previously expressed, one need to mention also the fact that the President of the country has some relations or activities/responsibilities that imply the collaboration of all three state powers. Therefore, being a mediator among these state powers, the President maintains some connections with these powers, as it is clearly stipulated in the fundamental law of the country.

### **4. The institutional relations between the Presidents and the Parliament**

From the very beginning of its mandate, the activity of the President is in direct relation with the Parliament. The President starts the mandate by taking an oath in front of both chambers of Parliament, reunited in a common session. It is a very solemn activity that implies something that was very hard to achieve in history, namely a democratic transfer of the first position in a state. Usually, having such a solemn character, at this event, besides the members of Parliament, other personalities are invited, like the Chief of Church, former Presidents...etc. In doing this activity, the Parliament has no direct responsibilities, it only takes note of the President's oath and the beginning of his/her mandate. Based on the Revised Constitution of Romania, the mandate of our President is of 5 years and not 4 years as it used to be. The timing is clearly stipulated and cannot be exceeded, except the situation when the Parliament decides this through an

organic law. Even in this case, the procedure could be initiated in a particular context, like a state of war or other similar disasters. These particular situations are used to justify the necessity for prolonging the President's mandate. The decision belongs to the Parliament exclusively, and the Parliament has the possibility, not the obligation, to prolong the President's mandate, even if the country is in the case of war or other disasters.

Another institutional relation between the President and the legislative power is that when the President has the possibility to address some messages to the Parliament. These messages could touch various topics, situations, problems and decisions concerning the Romanian population. In addition, their role is rather informative and could eventually determine some legislative effects. Consequently, the legislative power, using the messages received from the President, can initiate normative acts, in order to offer legislative solutions to the identified problems. This could be predicted since the President is not able to initiate any ordinary or organic laws, the only prerogatives in this sense being the possibility to initiate some changes in the Constitution.

Since the President is not able to initiate laws, he/she has other rights and duties in the legislative process. Therefore, the President is responsible for enacting the laws. This activity should not be confused with the right to sanction laws or with a possible veto power that Presidents in other legislative systems have. Before our laws are made public through the Official Journal, basically before they actually start to produce legal effects, they should be enacted by the President, after already being approved by the Parliament. Basically, after the President receives the law from the Parliament he/she has 20 days to enact it. In the case when he/she considers the law should not be enacted in the form adopted by the Parliament, the President has the possibility to send it back to the Parliament, institution that is obliged to receive it and to put it back to the agenda of discussions and debates. The Parliament has the possibility to modify the law according to the remarks made by the President, or to adopt the law again in the same form that was initially sent to the President. After the law is adopted again, it is sent again to the President. Now, the President has only 10 days to enact it. In addition, the President cannot send it back to the Parliament for a new debate and has no other power to reject it. Separately, the President has another legislative procedure at disposal – the possibility to address the Constitutional Court, but only based on some aspects that are against the constitution, and not on the way the considered social relations are regulated. Of course, if the institution that has the power and competency to decide whether the proposed law is against the constitution, then the law will not enter into force and a further harmonization with the fundamental law is then necessary.

The President of Romania has the power to dissolve the Parliament. In this respect one could consider that the President has vast powers, since he/she has the possibility to entirely stop the activity of the legislative power. In reality, things are a little bit different. First of all, it is about a supplementary role: *The President...can*, that means is not obliged to dissolve the Parliament. In addition, such a decision would only be taken in a specific context that entails some specific conditions and deadlines. Indeed, it wouldn't be normal for only one person, even if it is the President, to have such great powers that could easily eliminate the Parliament, the most representative and democratic institution from our political system. Such a prerogative, that can easily dispose the faith of the Parliament in any context, even based on personal interests, is rather specific to authoritarian regimes. In terms of the specific conditions and deadlines related to the possibility for dissolving the Parliament, there are different possibilities that could easily become sources for future legislation. According to the current Constitution, the President is able to dissolve the legislative power, only if this last institution did not invest the Government and rejected at least two requests for governmental appointment. Another situation is that when more than 60 days pass after the first request to invest the Government (Romanian Constitution, art. 89). It is only in this context that the President can propose such an extreme measure. In addition, there are other aspects that need to be taken into consideration: the Parliament cannot be dissolved twice in a year and in the last 6 months from the President's mandate. Having all these in mind, and the type of institutional relations between the President and the Legislative Body, we can conclude that the conditions for dissolving the Parliament are very strict, making this possibility rather theoretical than practical and possible.

Since the President is able to initiate the organization of a consultative referendum, on diverse topics of national interest, in order to do this, he needs to firstly address the Parliament (Romanian Constitution, art. 90). Still, the Parliament has no power and possibility to stop the presidential initiative to consult the population through a referendum. In complex situations, like war for instance, the institutional relations between the President and the legislative power are different, as the deadlines and procedures are usually shorter and easier. In a situation, where the state is threatened with war or similar military aggressions, the President, in his quality of Supreme Army Commander, can decide on the army mobilization. The army mobilization could be either partial or total. In this sense, the President needs the Parliament's approval, before enacting the decree of mobilization. In some particular situations where there is an urgent need for decisions, this approval could also be obtained after the decree of mobilization was enacted (Romanian Constitution, art. 92). The cooperation between these two entities is vital, especially in these extreme cases, as army aggressions or actual war. The simplification of these procedural decisions as well as avoiding the overlapping of competences are important for creating a sort of freedom of acting and decision for being able to reject the military aggressions and to defend the country.

## **5. The Institutional Relations between the Parliament and the President**

If the President can decide on dissolving the Parliament, in the above-mentioned conditions, The Parliament has also prerogatives for suspending the President. It is actually the case of suspension, since the decision regarding the remaining or the dismissal of the President does not belong to the Parliament but belongs to all the citizens having the right to vote. In this sense, all the citizens with the right to vote, through a referendum, organized in maximum 30 days after the Parliament decided on the President's suspension, decide whether to dismiss him or not. The reasons for this suspension should be the infringement of the fundamental law by the President, and this decision should be taken by both chambers in a common session. In terms of procedures, the initiative should belong to a third of both senators and deputies, and the suspension could be disposed with the vote of the majority of the members of Parliament (Romanian Constitution, art. 95). This type of institutional relation is extremely important. In theory, based on the existent doctrines, we can have three situations: one in which the Parliament can dismiss the President, the second one in which the Parliament could not decide on this situation in any case, and a third one in which the Parliament could only suspend the President. In the Romanian legislative system, the crafters of our Constitution opted for the third possibility. We should not forget that Romania is a semi-presidential republic, and that the types of institutional relations between the three powers are retrieved both from the parliamentary regime type, as well as from the presidential one. Consequently, if the President can decide on dissolving the Parliament in some specific conditions and with some specific limitations, the Parliament can also suspend the President following some strict procedures, but the final decision about dismissing the President is in the hands of all the citizens that enjoy the right to vote.

It is also the Parliament that can dispose another procedure for accusing the President of High Treason, a very serious offence, that attacks the fundamental interests of our country and that, of course, has serious effects. The decision to start the procedure for this accusation can be taken with a qualified majority of 2/3 from all the senators and deputies, reunited in one common session, called for this particular reason. The first effect of such a decision is the suspension of the President. Not even in this particular case does the Parliament have competencies to decide on the President's dismissal. In this situation, the competency for solving this situation belongs to the Supreme Court of Justice, as it is the only institution which can decide whether the President is guilty or not for what it's being accused off (Romanian Constitution, art. 96). Consequently, the possibilities when the Parliament has to sanction the President are rather limited and refer only to the President's suspension, and definitely not to the President's dismissal.

In order for the state to function in a predictable and balanced way, two general ideas should be respected when deciding the organization of state institutions and their competences. Therefore, the state powers should not belong to a single person and a single entity, this being very clearly stipulated by the separation of powers theory. In the same time, the means and competences that all these powers or state institutions have should not exceed those others have. More precisely, there shouldn't be left any possibility for creating a superpower. In this case, of course, we cannot talk about a real separation of powers, but rather a subordination of state powers.

## **References**

- The Romanian Constitution;  
Dănișor Dan Claudiu, Dogaru Ion, Dănișor Gheorghe – *Teoria generală a dreptului*, Second edition, publishing House: C.H.Beck, Bucharest, 2008;  
Dănișor Gheorghe – *Filosofia drepturilor omului*, Universul Juridic, Bucharest, 2011;  
Manta Pantelimon, Răvaș Oana, Cilibiu Maria Octavia, Manta Claudiu – *Drept administrativ*, vol. I, Publishing House. Pro Universitaria, Bucharest, 2014;  
Mihai Gheorghe – *Teoria dreptului*, Publishing House All Beck, second edition, Bucharest, 2004;  
Muraru Ioan, Tănăsescu Elena Simina – *Drept constituțional și instituții politice*, 15<sup>th</sup> edition, revised, vol. II, Publishing House C.H. Beck, Bucharest, 2016.

## Modern Approaches of Banking Globalization

Valentina Fetiniuc<sup>a\*</sup>, Ivan Luchian<sup>a</sup>, Alexandra Tvircun<sup>b</sup>

<sup>a</sup>International Institute of Management IMI-NOVA, Financial Management, Hristo Botev Street, No. 9, MD 2043, Chisinau, Republic of Moldova

<sup>b</sup>Accent Group, Business Development, Bulgara Street, No. 33/1, MD 2001, Chisinau, Republic of Moldova

---

### Abstract

Globalization has become main trend, characterizing the development of modern financial market and affecting primarily the functioning of global banking system. Because of this process is distinguished banking globalization as a specific form of financial globalization. Banking globalization has specific issues. It is manifested by fundamental changes of global banking system functioning and elsewhere by modifying the quality of banking activity. It promotes the standardization of national banking systems and emergence of a single, dominant banking model. Banking globalization conduct a process of concentration and consolidation in banking sector that promotes the expansion of banking options. This process has both positive and negative aspects. Globalization banking contributes to strengthening global banking system, which takes place simultaneously with concentration of banking capital. In addition, unification standards occur, which runs simultaneously with deregulation of banking business and liberalization of financial markets. This erases institutional distinction between different types of banking and financial activities. Important aspects of banking globalization are deepening of banking competition and innovation process, which contributes to increase of banking services range and quality. It contributes to implementation of new technologies, giving opportunities to wide spectrum of banking products and their quality raising. Along with the above, it must mention that banking globalization causes a range of new problems, which constitute new challenges for regulators. The article will contain an analysis of all the basic aspects of financial globalization, as well as their conclusions.

*Keywords:* bank, banking globalization, transnational banks, banking technologies

---

### 1. Introduction

Banks have a dominant position in the financial market. That's why they become main participants in the process of financial globalization and exert an active influence on financial markets, stimulate their integration and modernization while simultaneously changing themselves.

Many researchers point to the fact that current trends in globalization of economy contribute to transforming the role of bank into economic system, becoming the important financial intermediary that provides all participants of international economic activity with necessary financial resources. As a result, banks not only carry out international financial activity as autonomous institutions but also contribute to international business of other economic entities.

The transformation of global banking system is a complex mechanism consisting of all the economic, social-economic, political and geopolitical problems that differ in their degree of mutual influence, combination and confrontation of evolution vectors. The controls on this system, on the one hand, are required to adapt to these processes and elsewhere to change them in their interests, but these processes can only be influenced by countries with a high potential and obvious competitive advantages.

Also, experts point out that in financial sphere globalization has determined the necessity of cardinal changes in banking market in general, as well as in foundations of commercial banks' activities, approaches and realization by banks of market strategies and change of corporate management in the field banking.

---

\* Fetiniuc Valentina. Tel.: + 373-22-56-87-38, +373-689-777-86; fax: + 373-22- 56-83-03.  
valentinafetiniuc@yahoo.com

## 2. Banking globalization overview

### 2.1. Banking globalization definition

Banking system is the most flexible tool for capital mobilizing and, therefore, should be the most sensitive to any changes in the financial market. In the context of globalization as result of international nature banking system performs the link of global financial system, which is one of the first to feel the impact of financial globalization. (Davlatov, 2015)

Banking globalization is the stage where banking services have spread worldwide, becoming universal. (Savu, 2006)

It is a separate direction of economic globalization. As result of banking globalization change the nature and forms of competition on financial market. Banks are forced to compete simultaneously on many financial market segments, not only with each other but also with other financial institutions: insurance companies, investment funds, non-state pension funds and other financial companies. (Davlatov, 2015)

At the same time, banking globalization represents the highest degree of international banking development, which is reflected in the implementation of commercial banks transactions with foreign counterparts and on global financial markets. International banking business has developed along with development of world trade, international business of non-financial institutions.

Financial globalization also observed processes of deregulation of banking business and liberalization of financial markets, which has an impact on nature of international banking business. Institutional distinctions between different types of banking and financial activities are removed: commercial, investment, insurance and other. This leads to a change in nature and forms of competition in the financial markets. Simultaneously competition in many financial market segments is growing. Competitors are not only banks with other banks, but other financial organizations in a liberalized environment are both residents and non-residents. Liberalization also entails the extension of territorial diversification of banking business on global scale. It contributes to international banking business expansion.

Banking globalization has shown rises in following areas (Claessens, Marchetti, 2013):

- Increase in direct cross-border banking, foreign direct investment and other forms of capital movement, in particular portfolio investment in equity and bond instruments;
- Creation by banks of institutions with the participation of foreign capital, including banks, and activity in other states. Over the past decades, banks have widened their global presence by creating subdivisions of operations in branch and branch forms.

The notion of banking globalization is closely linked to *international banking*, which presupposes the existence of a wide network of credit institutions abroad, high proportion of foreign operations as well as high degree of dependence of size of their income from foreign sources. For international payments, banks use their foreign offices and branches, any correspondent relationships with foreign banks without establishing a legal entity.

Main forms of output of commercial banks to foreign market is opening of representative offices, branches, agencies, subsidiaries of banks and other, less common in organizational and legal terms of institutions. International banking activity without establishing a legal entity abroad includes conclusion of agreements on correspondent banking relationships, participation in payment and settlement systems (SWIFT-type), establishment of banks and other invisible forms. Increasing share of foreign operations in total volume of banking operations and services, they establish close correspondent relations with hundreds of thousands of banks in all parts of the globe, creating their own foreign vehicle, participating in bank consortiums and alliances allow qualified industrialized nations largest banks not only as universal, but also as an international. (*Международная банковская...*, n.d.)

Specialists in the field now apply the concept of *global bank*, which is linked to the installation of ultra-refined electronic systems and while engaged in transactions in dozens of centers throughout the globe. (Savu, 2006)

Formation of infrastructure of global banks requires a very large spending, which cannot bear only most solid groups. For centralized processing of huge volumes of transactions, providing wide range of services and information to meet the needs, big banks create one or more own specialized entities, performing an intense activity. (Savu, 2006)

The literature now uses the notion of *global banking* which implies the presence of powerful financial institutions in various world markets, as well as their knowledge of economic situation, financial services industry, state housekeeper sectors and cultural characteristics of each specific country in a given region. This suggests that global banks were able to provide a full range of financial products and services, the most suitable for a particular financial market, as well as offering innovative banking solutions for both local and for cross-border customer needs, which are often large multinational companies. Revenues of global financial institutions are relatively evenly distributed over geographic area and cannot be extracted mainly from any one market segment or region. (Zaitsev, 2010)

### 2.2. Global financial system evolution

According Wikipedia *global financial system* it „is the worldwide framework of legal agreements, institutions, and both formal and informal economic actors that together facilitate international flows of financial capital for purposes of investment and trade financing”. (*Global financial...*, n.d.)

Since emerging in the late XIXth century during the first modern wave of economic globalization, its evolution is marked by the establishment of central banks, multilateral treaties and intergovernmental organizations aimed at



improving the transparency, regulation and effectiveness of international markets. In turn, an important element of the global financial system is global banking system. (*Global financial...*, n.d.)

The *global banking system* is international economic category, which expresses the ratio of different interconnected banks and other credit institutions of different countries working in the framework of international financial system, on provision of banking services. (*Международная банковская...*, n.d.)

Global banking system is defined structure in modern literature as a system with a four-layer (Vasina, 2015), (*Классификация международных...*, n.d.):

- *Supranational banks and financial institutions*;
- *Central banks*;
- *Global transnational banks (TNB)*, which have widely ramified system of subsidiary banks, as a rule, much of TNB capital is withdrawn from jurisdiction of central banks governing their activities. TNB are largest banking institutions that have achieved a level of international concentration and centralization of capital, which gives them the opportunity to participate meaningfully in economic distribution of world market of loan capital and monetary resources (credit and financial services). They are the core of global banking system. They are carried out basic movement of international financial flows. They are major holders of foreign exchange reserves and is concentrated in countries where are present liberal tax laws and exchange rate regime for credit operations. (*Международная банковская...*, n.d.);
- *International commercial banks*, which international operations provide 5 to 10% of their income. To gain a competitive international reputation of such bank, this is clearly not enough. These banks are increasing their participation in international operations through creation of separate branches and representative offices in major international financial centers, performing wholesale monetary and credit transactions, including participation in various international loan agreements. Foreign network of banking institutions is subordinate and generally perform a passive role;
- *National commercial banks* with only one small foreign branch, which accounts for a small share of assets, revenues and personnel. Such branch finance trade agreements, non-recurring foreign exchange transactions, provide services using letters of credit to customers in host country, carry out limited correspondent relationships with other banks.

Thus, the global banking system is (Vasina, 2015):

- 1) *Complex*, consisting of many elements;
- 2) *Organic* - has a complete hierarchical structure created by development of world economic relations;
- 3) *Continuously evolving system* - transformed at certain stages of development history;
- 4) *Consisting of set of interacting elements in global scale* - international economic organizations, central banks, TNB, commercial banks;
- 5) *Increasing complexity in process of historical development* - elements included in new communication; in framework of integration process is modified financial architecture;
- 6) *Close interaction with environment* as subsystem of global financial system and, more broadly, world economic system.

At the moment, the world banking system is developing in following directions (Fetiniuc, Luchian, 2013):

- a. Unification, standardization, national legislation on banking activity given in conformity with the international standards of banking;
- b. Development at the international level in accordance with the Basel Agreement (standards) of common approaches to evaluation (analysis) the financial status of the commercial banks of banking supervision bodies;
- c. Creation a single management and regulation institution of banking activities in the face of a world Central Bank. A prototype of the global Central Bank is currently the European Central Bank (Frankfurt am Main), which in 1999 was due to the ongoing process of integration in Europe within the EU.

The transformation of global banking system is a complex mechanism consisting of all economic, social-economic, political and geopolitical problems that differ in their degree of mutual influence, combination and confrontation of evolution vectors. The controls on this system, on the one hand, are required to adapt to these processes and elsewhere to change them in their interests, but these processes can only be influenced by countries with a high potential and obvious competitive advantages.

Some authors point out that in financial sphere globalization has determined the necessity of cardinal changes on banking market in general, but also in fundamentals of commercial banks' activities, approaches and realization by banks of market strategies, as well as the change of corporate management in banking.

These transformations were determined by the following factors (Vlezkova, 2012):

- Increasing the dependence of national banking systems on international capital market;
- Strengthening competition on global financial market between both banks and banks with other financial institutions;
- Increasing the opening of national economy;
- Standardization of banking supervision;
- Development of information and communication technologies.

Roman investigator Savu (2006) indicate *banking alliances* as possible alternative to traditional farming methods, taking various forms of distribution agreements of financial products and services to create a new entity. They have multiplied, providing for specific advantages in relation to internal growth and restructuring.

The size of banking alliance determines the competitiveness backed by a diverse range of products, cost-effectiveness information related to financial activities and maintaining a global network of customer. (Savu, 2006)

Among advantages of banking alliance may be mentioned (Savu, 2006):

- Saving money and reducing their costs of penetration of foreign markets;
- When significant capital investment is making, all alliance partners are involved;
- Banks keep a relative autonomy and enable them to break the agreement;
- Bank may choose the partner for certain activities only;
- Alliance management is much easier to acquisitions or mergers;

Through alliance bank can penetrate a market where access is difficult.

### 3. Fundamental directions of banking globalization

#### 3.1. Main features of banking globalization

According to some economists, banking globalization determines the transformation of banking business as follows (Samarina, 2011), (Vlezkova, 2012), (Davlatov, 2015), (Gabbasova, Mirzagaleamov, 2015):

- *Increasing share of international operations* in total volume of banking transactions.
- *Increasing influence of growing expansion of corporations* on national monetary policy (ie. central bank activity) has, banks and other financial institutions in global capital markets, including in direct investments sector.
- National banking systems, which are designed to accumulate and redistribute financial resources within national economic system, are *in ever-increasing dependence on international capital markets*, which in era of globalization has become an independent factor in development of world economy.
- Development of a network of transnational corporations and their affiliates around the world has led to increase in their need for adequate banking services and provoked *emergence of new non-traditional banking services*.
- Non-financial sector of economy, financial and banking systems of national economic systems are becoming more standardized at work in domestic and global markets. This leads to convergence of regulating rules of internal and external economic transactions. Process of financial globalization and formation of global banking industry promote the *standardization of national banking systems* and emergence of *single, dominant banking model*. It can also be about *standardization of banking supervision*.
- *Concentration of capital*, including the merging of insurance and banking capital, lead to formation of transnational financial corporations, which capital is spreading beyond national economies, size of assets of corporations is comparable with budgets of entire countries.
- It takes place *banking management objectives adaptation*. The main of which consists in to enhance market capitalization of the bank as a company. The increase of market value of bank and increase of capitalization of banking industry in general ensure compliance with their banking socially significant features that contributes to economic growth.
- *International portfolio investments is growing* which enhance active banking operations.
- Globalization is accompanied by *deregulation of banking business* and the *liberalization of financial markets*. This erases the institutional distinction between different types of banking and financial activities (commercial, investment, insurance, and others). Liberalization, on one hand, creates conditions for development of an overseas branch network of banks and formation of international banking business, which naturally increases the competition, but on other hand, at the same time activates consolidation of bank capital. This leads to increase of mergers and acquisitions number in banking sector, to expand and increase the diversity of banking cooperation between themselves and non-bank financial institutions, growth of bank alliances of all kinds.
- *Substantially change nature and forms of competition in financial markets*. Banks are forced to compete simultaneously in many financial market segments, not only with each other but also with other financial institutions (insurance and investment funds, finance companies, etc.) and in liberalized environment - not only with residents but also with non-residents.
- Banking, globalization is associated with the *reorientation of banking business from traditional to innovative*, reducing the share of traditional banking operations in favour of increase of new, qualitatively meeting of customers needs changing. Improvement of banking products and services, channels of their promotion on modern information and communication technologies, carrying out to achieve adequate compliance of banking business to changing customer demands.

Researcher Kozimenko (2002) is of opinion that banking globalization has some positive features:

- Using of high standards for the quality of services, information and reporting;
- Obtaining of additional funding for its own asset and liability management;
- Access to additional markets and capital flows;
- Introduction of new products;
- Independence from processes taking place in internal market;
- Increasing of diversification degree;
- Obtaining of sufficiently favourable liquidity;

- Availability of opportunities to better capital allocation;
- Application of professional risk management technologies, optimization of management systems, etc.

Under conditions of globalization, processes of banking activity deregulation and liberalization of financial markets are also taking place, which influences the nature of international banking activity. The elimination of institutional boundaries between different forms of banking and financial activity takes place: commercial, investment, insurance, etc., which leads to a change in the nature and forms of competition on financial markets. At the same time, there is competition on many segments of financial market.

Liberalization leads to the widening of territorial diversification of banking activity on a global scale and leads to amplification of international banking activity. At the same time, the elimination of entry limits on national banking markets for non-performing financial institutions has opened wide possibilities for development of banks' branch network abroad and the formation of international banking activity, which has strengthened and complicated competition.

The lifting of barriers to delimitation between different forms of activity and geographic regions broadly broadens the spectrum of services provided by banks and capital consolidation processes lead to formation of financial conglomerates with a complex structure.

As a result, banks face a large number of diverse financial and non-financial risks, which tend to diversify, which complicates the risk management system and raises the importance of financial management in banks.

The top management of banks does not always manage to properly assess risks of specialized activities even with modern risk management systems. That is why large banks are actively seeking new management models based on decentralization principles and at the same time refine strategic management approaches that become the determinant factor of future competition on international capital market.

An important feature of national conetmporan markets development and of world economy is the increased concentration of capital and productions in different spheres of economic activity. Analyzing this issue, it should be noted that expansion of international banks, strengthening of non-banking financial institutions positions, formation of a strong segment of online and mobile banking services lead to a high level of competition and at the same time activate processes of capital consolidation banking, being motivated by tendency to preserve and strengthen competitive positions. In many countries, the number of acquisitions and mergers in banking sphere has increased, forms of co-operation between banks and the non-banking financial institutions have widened and diversified.

### 3.2 Globalization and new banking technologies

It should be noted that the latter factor has a crucial role in the processes of transformation on banking market:

- Development of information technologies contributes to efficient collection and processing of information and cost reduction of providing banking services.
- Due to information technologies, banks have gained 24/7 access to financial markets and have been given new opportunities to develop new banking products.
- Maintaining long-term relationships with customers of wide network of subsidiaries gradually diminishes their importance. The new generation of customers prefers growing use of banking product in cyberspace.
- New technologies reduce information asymmetry, increase market transparency, make customer information more accessible and, as a result, banks lose the benefits of exclusive business partners.
- Customers get the opportunity to choose convenient bank product offers.
- Based on new information technologies, some non-resident and non-banked non-bank institutions can provide some banking services (eg payments).
- Advancement of information technologies has created premises for development of banking innovations.

It should be noted that information technology, as well as globalization, changing conditions of competition in the banking industry, making it more hard for banks. They provide the transparency of market, enable customers to choose the most advantageous offer for their services. Also, based on new technology banking services (for example, payment transfer) may have organizations other than banks, including communication firms. (Vlezkova, 2012)

Hence, the characteristic tendency of global banks' activities which is to provide a new and expanding well-established delivery channels of banking products and services to customers. *Electronic banking* has significantly expanded the scope of coverage of consumer financial services, primarily limited by operations of traditional bank branches. (Zaitsev, 2010)

In connection with use of the Internet appeared the notion *virtual bank*. According Business Dictionary it "Internet based financial institution that offers deposit and withdrawal facilities, and other banking services, through automated teller machines or other devices, without having a physical (brick and mortar) walk-in premises". (Virtual bank, n.d.)

Another trend continues to be *outsourcing of certain functions and global banking operations*, which is logical, where these functions are routine, and some banking services have become a homogeneous product. As a rule, the main reasons due to which global financial institutions are outsourcing lie in desire to reduce costs, to replace permanent (fixed) costs variables, as well as to focus attention on running core business. According to experts, there are several ways in which global banks carry out outsourcing of their functions and operations. Firstly, an important role is played by geographical factor when banks transfer some of its functions in maintenance of outsourcing companies from

countries with cheap labor. Some data centers (processing centre) here serve one client, ie, one global bank, other - a few clients at a time. (Zaitsev, 2010)

Another notable trend in global banking sector is *further improvement of the integrated risk management (complex risk management)* as a way to identify, evaluate and control effect of internal and external factors, change of which may adversely affect value of portfolio or bank as a whole. (Zaitsev, 2010)

#### 4. Conclusions

Globalization has become main trend, characterizing the development of modern financial market and affecting primarily the functioning of global banking system. This process is distinguished in such degree that at the moment we can talk about banking globalization that has a contradictory character. On the one hand it promotes the standardization of national banking systems and emergence of a single, dominant banking model. Banking globalization is accompanied by a process of concentration and consolidation in banking sector that promotes the expansion of banking options. In addition, globalization is accompanied by deregulation of banking business and liberalization of financial markets. This erases institutional distinction between different types of banking and financial activities. Important aspects of banking globalization are deepening of banking competition and innovation process, which contributes to increase of banking services range and quality.

#### References

- Claessens, Stijn; Marchetti, Juan A. (2013) *Global Banking Regroups*, <http://www.imf.org/external/pubs/ft/fandd/2013/12/claessens.htm#author>, [Accessed 26 February 2018]
- Global financial system*, [https://en.wikipedia.org/wiki/Global\\_financial\\_system](https://en.wikipedia.org/wiki/Global_financial_system), [Accessed 16 February 2018]
- Fetiniuc, Valentina; Luchian, Ivan (2013) *Modern Features of Financial Globalization*. Annals of The University of Petroșani. Economics. Vol. XIII. Part I. Petroșani. 2013. p. 117-128
- Savu, Emanuela Mihaela (2006) *Tendințe privind globalizarea sistemului bancar internațional*, Economie teoretică și aplicată nr. 6 / 2006 (501), p. 87-94
- Васина, М. Ю. (2015) *Мировая банковская система: трансформация в условиях глобальных финансовых дисбалансов*, <http://cyberleninka.ru/article/n/mirovaya-bankovskaya-sistema-transformatsiya-v-usloviyah-globalnyh-finansovyh-disbalansov>, [Accessed 26 February 2018]
- Влезкова, В.И. (2012) *Влияние глобализации на банковские структуры: трансформационные процессы*, [http://law-journal.ru/files/pdf/201206/201206\\_157.pdf](http://law-journal.ru/files/pdf/201206/201206_157.pdf), [Accessed 24 February 2018]
- Габбасова, Л.Б.; Мирзагалямов, Б.Б. (2015) *Тенденции развития международной банковской конкуренции в условиях глобализации*, <http://cyberleninka.ru/article/n/tendentsii-razvitiya-mezhdunarodnoy-bankovskoy-konkurentsii-v-usloviyah-globalizatsii>, [Accessed 26 February 2018]
- Давлатов, И.Х. (2015) *Экономическая природа глобализации и ее влияние на банковскую систему Таджикистана*, <http://www.socionauki.ru/journal/articles/300145/>, [Accessed 24 February 2018]
- Зайцев, Олег (2010) *Банковская глобализация*, <http://www.web-standart.net/magaz.php?aid=9644>, [Accessed 24 February 2018]
- Классификация международных банков*, [http://studbooks.net/3563/finansy/klassifikatsiya\\_mezhdunarodnyh\\_bankov](http://studbooks.net/3563/finansy/klassifikatsiya_mezhdunarodnyh_bankov), [Accessed 22 February 2018]
- Козьменко, С.Н. (2002) *Финансовая глобализация и перспективы банковских структур*, <http://dspace.uabs.edu.ua/jspui/bitstream/123456789/2111/1/Kozmenko,2002,T.6,Problemu.pdf>, [Accessed 27 February 2018]
- Международная банковская система*, [http://studme.org/1685030319832/ekonomika/mezhdunarodnaya\\_bankovskaya\\_sistema](http://studme.org/1685030319832/ekonomika/mezhdunarodnaya_bankovskaya_sistema), [Accessed 24 February 2018]
- Самарина, Т. С. (2011) *Банковская система России в условиях глобализации*, <http://www.lib.csu.ru/vch/246/025.pdf>, [Accessed 23 February 2018]

## Performing University Management - A Determinant Factor in Quality Assurance in Education

Roxana Plesa<sup>a</sup> \*

<sup>a</sup> University of Petrosani, 20, University Street, Petrosani, 332006, Romania

---

### Abstract

The quality of an educational system is reflected not only in the instructive performances of the educational actors, but also in the degree in which it ensures an adequate professional integration. The motivation of this research is closely connected to the improvement of the level of communication between the two aspects –the academic one, by its finite products, and the economic one, by job offer. The study set sights on over 29 of the most important employers from the Jiu Valley, and 39 of the graduates of the University of Petroșani. Data were collected in 2016 year, through a survey oriented as well as for the employers and graduates. The research based on the quantitative questionnaire was structured on 21 questions for the employers and other 25 questions for the graduates, of which 8 were common for the two lots of subjects, by which comparable results have been constituted between the requirements and expectations of the two parties involved in the labor market. Statistical data processing was done using SPSS program (Statistical Package for the Social Sciences).

*Keywords:* University Management; Employer; Graduate; Education; Quality; Labor Market; Skills

---

### 1. Theoretical Framework

Contemporary society is defined as a knowledge and learning society, an information society in which real flows of goods and services are replaced by information flows through a virtual economy in which the sustainable factor of progress is generated by the continuous improvement of human capital. The emphasis is on the quality of individual life, on major transformations of a qualitative nature of living standards. All this is only possible in those societies where the educational institution actually fulfills its social mission, assuring quality education, effectively contributing to the construction and affirmation of the new society. Taking into account social development, documents drawn up by the Ministry of Education and Research, in collaboration with the European Center for Higher Education and UNESCO, highlight: "Numerous demonstrations prove that today's developed societies and especially tomorrow's are more and more knowledge and learning societies. Procedure, transmission and application of knowledge in any field of activity are courts that increase productivity. Also, without lifelong learning, personal adaptability or individual way and style are poorer in content and performance, decreases the quality of life in terms of economic standards, the diversity and depth of cultural actions or experiences. Intelligence based on knowledge and professional competence constantly upgraded by assimilating new skills and knowledge is the sign of a personal quality of life capable of contributing to the development of the national and local community. "(MEN, CEPES, UNESCO, 1998 apud <http://www.preferatele.com/docs/management/noi/managementul-perform11206231719.php>).

#### 1.1. Effectiveness of knowledge management

Given that the decentralization of the education system is becoming increasingly strong, the effectiveness of knowledge management increases substantially if the educational institution proves your concern for a careful analysis of the external environment, thus offering other information about their own activity. Decentralization of education implies involvement, responsibility, change of tactics approaching the educational process, strategies, a new management of that institution and a services offered by it. (Ciolca, 2012). This, especially given that the Romanian university system is obliged to adapt its educational offer to the current demands of the labor market. Otherwise, the

---

\* Corresponding author. Tel.: 0744611230  
E-mail address: [rpmitta@yahoo.com](mailto:rpmitta@yahoo.com)

number of graduates leaving the country will increase each year. Actions aimed at improving the management system of the school, as it is knowledge is integrated into this system, it mainly targets: conceiving the management system of the education unit and redesigning it on rigorous scientific bases; remodeling the school development strategies corresponding to the stage requirements the current development of the Romanian society, characterized by the transition to market economy and restructuring of the national economy; the decisive role of strategic and tactical decisions, risk and uncertainty, and those economic growth in rationalizing decision-making and accelerating profitability; training of educational managers according to the requirements of European education. (Ciungu, 2005).

Management of the system and educational institutions involves activities that make use of: clear formation of finality; designing the institutional network (types, profiles and specializations, location in the territory in relation to certain criteria); developing the content of learning (the official curriculum); ensuring the legislative framework necessary for the achievement school policies and financial resources; initial and in-service training of teaching staff; establishing evaluation techniques to optimize results. (Cristea, 2004). At central level there is a strategic management guiding, guiding and evaluating the entire system education, at the level of institutions is practiced one operational management to implement the strategy developed at a higher level. (Ghergat, 2007). An important indicator on the efficiency of the organization's educational management is the dynamism of the conception and realization of the actions, the entrepreneurial spirit that it is both the leaders of the institution as well as the teaching staff and the other employers. The beat accelerated changes in all areas of activity, the specific requirements of the economy market, require an increase in the response rate of all the factors that work in a learning unit. Initiation and dynamism have an increasing influence on the effectiveness of educational decisions and actions, being decisive in achieving a education which corresponds to the quality standards during this period of adaptation of Romania to EU requirements, which is based on the construction of a competitive type of economy in Romania which fast technical progress, the multitude of international contacts and profitability will be the main goals of the economic and social development of our country.

## 1.2. Managerial performance and performance management

Peter Drucker, a contemporary personality in the field of management, said: performance achieved through management is actually characterized and achieved in practice two dimensions: effectiveness and efficiency. Efficiency is the ability to choose the right and appropriate goals and reach them again efficiency is the ability to make the best use of the resources available in the process of achieving, respectively fulfilling the objectives. (<http://steconomiceuoradea.ro/anale/volume/2006/management-si-marketing/44.pdf>). In practice, managers need to balance the need for efficiency with the need for efficacy.

Educational management is a complex process of leading education at the level of the education system considered as a whole or at its structural levels and it includes the management of the educational act manifested under its informal and non-formal aspect. (Toca, 2002; Jinga, 2001).

Educational management combines the theoretical aspect (concepts, approaches) with the methodological aspect (information accumulation and processing necessary to carry out specific activities) with the appearance technologically (the concrete solution of different situations, processes, operations, stages) and managerial practice. (Orȃn, 2004). Any institution or organization providing services education is included in a specific environment that condition and influence the managerial process. The three specific environments are: educational, social and economic. The activities carried out by the educational unit manager in these three listed areas need to be harmonized in a manner that ensures overall performance.

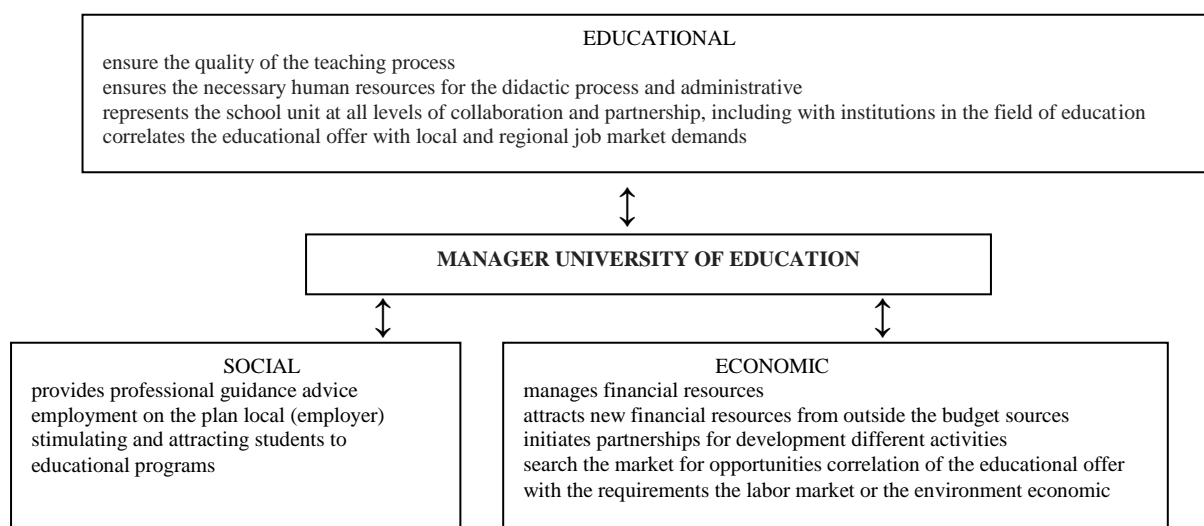


Figure1. Areas of activity of an educational unit manager

## 2. Results of the study

The socio-economic crisis that crosses the Jiu Valley in recent years, made the three important pillars in the development of this area - business, university and local government - to sit at the discussion table to determine which are business requirements in terms of human resource that provides university and how can local governments to support two media mentioned above, however the idea he wants to lay the foundations for sustainable development of the area Valley Jiu. The main question raised was that young people choose to leave this area to operate in other parts of the country. University requires from the businesses company owners, to create the conditions for young people to stay in Jiu Valley, and from the local governments the requirement was to create a conducive environment for investors that want to do business in this region.

The data presented in Figure 2 show the success of the action taken by the companies involved in the study, involving students interested in long-term internships, resulting in graduates with higher education, experienced in the workplace and motivated to remain active actors in the labor market work in the native country. In order to halt the emigration of young people with higher education, not only the labor market must be flexible and adaptable, but also the educational offer of higher education, the collaboration between the two environments being the essential condition for an adequate insertion on the labour market.

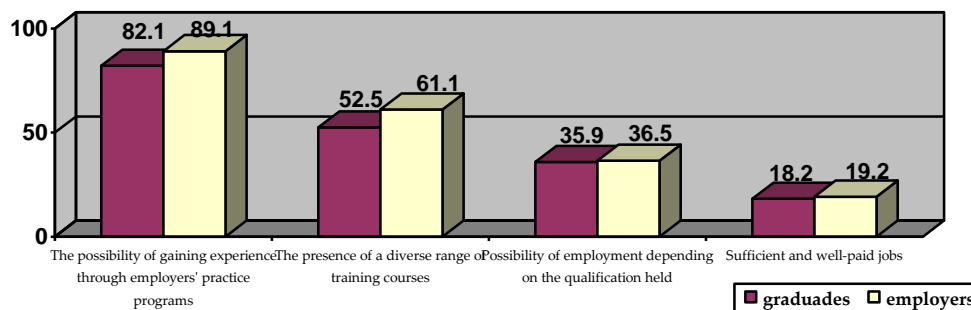


Figure 2. Labour market opportunities in the opinion of graduates and employers (%)

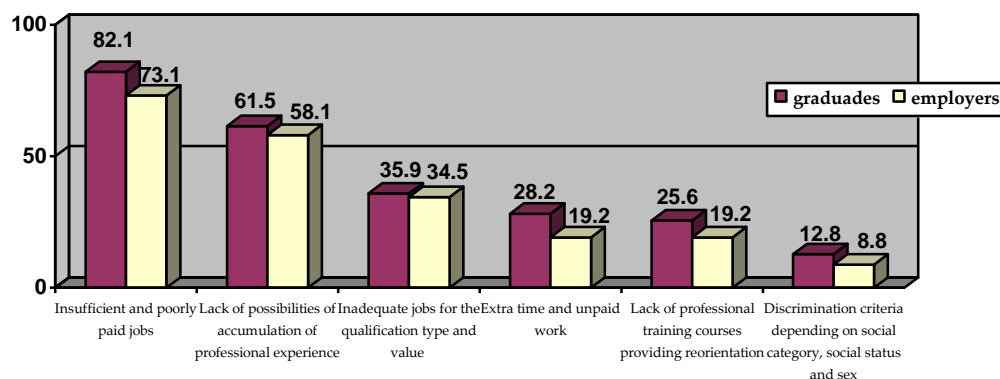


Figure 3. Labour market limits in the opinion of graduates and employers (%)

The comparison between the two lots of respondents points out a relative similarity of opinions regarding the limits existing in Romania's labour market. Thus, the variant with most of the choices, both of the graduates and of the employers, is represented by the problem of insufficient and poorly paid jobs. One should mention however, that with the graduates, among the aspects mentioned as limits of the labour market, we may also find lack of possibility of accumulating professional experience, a requirement that is absolutely necessary for hiring, but also the existence of jobs that do not match the value and type of qualification, an aspect which should be in the attention of the universities.

The comparison between the two lots of subjects of the study points out a perfect match of the hierarchy of activities intended to accumulation by the graduates of professional experience. Thus, in a percentage of over 85%, both graduates and employers rate first in the process of acquiring professional experience, entrepreneurial activities, which involve initiative and coordination of one's own activity or of a group, followed by activities involving interpersonal relationships, helping the others, educational activities, appreciated by more than three quarters of the respondents.

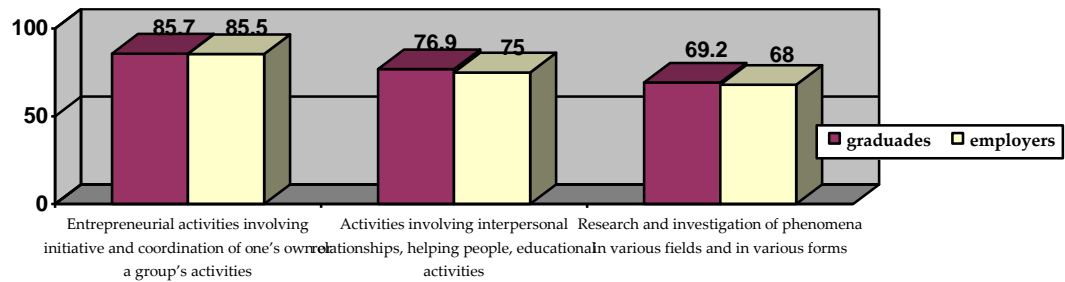


Figure 4. Importance of the following activities for accumulation of professional experience by graduates (%)

For the young at the beginning of their carrier, access to as much information as possible regarding the employing company, the expectations regarding the ideal candidate is important.

The same work experience is seen both by the graduates and the employers as key-element in carrier promotion and advancement, followed by the level of qualification attained, but also the existence of a personal and professional development plan, first of all by participating in training courses.

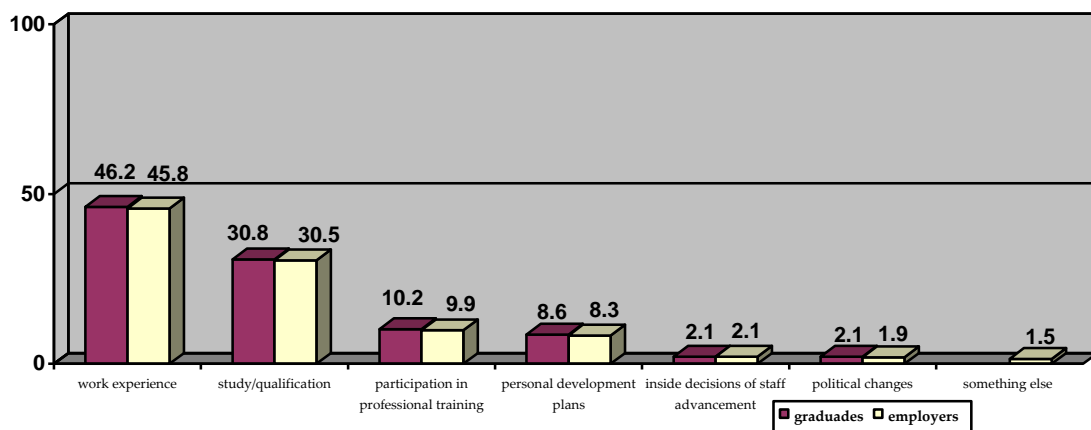


Figure 5. Carrier advancement possibilities, in the opinion of graduates and employers (%)

It is already known that when a university is graduated, the objectives in life are formulated generally, and the perception on the professional future is vague. Being in a continuous process of knowing their own selves, graduates will need instruments, strategies and methods that might help them discover themselves from a professional point of view, understand individual resources, but also their limits, so that they might build up medium and long term objectives, starting from these personal evaluations, being able to discover their abilities, but also their weak points in relation to a carrier they intend to develop.

Lack of self knowledge, of exploration of employment opportunities, preponderant centering on identification of a possible employer, without putting into balance one's own interests or values, make the entire decision process unsatisfactory. To this one might add the fact that most of the graduates put the responsibility for developing professional competencies on the University instead of their own person. The fact that the support in the professional course is done by academic means is a plus for the undergraduates, since it meets the needs and expectations manifested. Meanwhile, however we should take into account the fact that there is a risk of transforming the undergraduates into simple receptors. It is necessary to maintain the responsibility and confidence attributed to the academic environment, and meanwhile to encourage the development and assuming of one's own responsibility by offering practical exercises that might be achieved outside the academic environment, by orientation toward labour market, by support offered in developing a personal brand and training in social networks that might assist them in their professional course.



Table 1. Correlation between the importance given by the employer to the desire to investigate their own ideas or others and the need for higher education to improve other competencies

			The need for higher education to improve analytical thinking	The need for higher education to improve the ability to learn quickly	The need for higher education to improve the ability to open up for new opportunities	The need for higher education to improve the desire to investigate one's own ideas or others
Spearman's rho	The importance given by the employer to the desire to investigate their own ideas or others	Correlation Coefficient	,626**	,768**	,663**	,712**
		Sig. (2-tailed)	,002	,000	,001	,000
		N	19	20	19	20

\*\* . Correlation is significant at the 0.01 level (2-tailed).

Table 2. Correlation between the importance given by employers to analytical thinking and the need for higher education to improve other competencies

			The need for higher education to improve analytical thinking	The need for higher education to improve the ability to learn quickly	The need for higher education to improve the ability to mobilize the capacities of others	The need for higher education to find new ideas and solutions
Spearman's rho	The importance given by employers to analytical thinking	Correlation Coefficient	,616**	,597**	,717**	,597**
		Sig. (2-tailed)	,002	,002	,000	,002
		N	20	21	20	21

\*\* . Correlation is significant at the 0.01 level (2-tailed).

The pressure exerted at university level is also highlighted by the data presented in the correlation tables 1 and 2, obtained by calculating the Spearman correlation coefficient.

## Conclusions

The hypothesis on which our entire research was based, namely “We estimate that there are no significant differences between the labor market needs and the outcome of the educational system”, has been confirmed.

University of Petroșani wants to become a bridge between business and academia, so students trained here, could find a place in the labor market, and this approach management has been declared through the official event organized on June 15, 2016 at the headquarters university. Higher education institutions that address holistic activities can be characterized as having a responsible way of action, ensuring a high level of long-term competitiveness. It is therefore advisable for university management to understand and take into account the strategic context, impact area, and the importance of social responsibility. Then it is necessary to clarify the university objectives and implement the principle of social responsibility, taking into account the specific problems faced by the institution as well as its opportunities.

In our opinion, when it comes to reforming education, we must mainly focus on the evolution of education time of each level, from preschool to postgraduate and analyzed strengths and weaknesses. Like suggestions reforming the educational system, we go on the idea of highlighting strengths and balance between practical teaching and theoretical methods, focusing on the practical side, the introduction of counseling programs to help each preschool, student or student in a direction appropriate to him, be helped to make the right decisions through clear arguments, taking into account their desires, passions and talents. Also, another point to be correlated with the above, we could talk about the efficiency and the way of teaching, which, in our opinion, should be dynamic, based on innovation and interactive methods.

Universities have the necessary capacity to develop the intellectual framework in support of practical applications on the concept of sustainable development. Higher education institutions, as academic leaders, have the capacity to agree on academic disciplines on large and complex issues, to mobilize resources, to create incentives and programs for skills development, and most importantly to lead by example in to promote and implement sustainable development education.

## References

- Ciolca E.C., *Managementul programelor școlare în educație fizică și sport*, Editura Universitară, București, (2012).
- Ciungu P., *Managementul activităților didactice*, Universitas Publishing House, Petrosani, (2005).
- Ciungu P., Vătuțiu T., *Managementul educațional performant—condiție esențială a armonizării învățământului românesc cu cel European*, available at: <http://steconomiceuoradea.ro/anale/volume/2006/management-si-marketing/44.pdf>, accessed at: 20 May 2018.
- Cristea S., *Managementul organizațiilor școlare*, Editura Didactică și Pedagogică, București, (2004).
- Edelhauser E., *Sisteme informatice în managementul resurselor umane*, Universitas Publishing House, Petrosani, (2011).
- Ghergat A., *Management general și strategic în educație, ghid practic*, Editura Polirom, Iași, (2007).
- <http://www.preferatele.com/docs/management/noi/managementul-perform11206231719.php> accessed at: 20 May 2018.
- Jinga, I., *Managementul învățământului*, Editura Aldin, București, (2001).
- Orțan, F., *Management educațional*, Editura Universității din Oradea, (2004).
- Toca, I., *Management educațional*, E D P – S.A., București, (2002).

## Techniques To Continually Improve Business Quality And Performance (I)

Ghicajanu Mihaela<sup>a\*</sup>

<sup>a</sup>*University of Petroșani, Petroșani, Romania*

---

### Abstract

The continuous improvement techniques applied in quality management have their origins in the Japanese Kaizen philosophy which Deming simply described it as "Improving initiatives that increase success and reduce mistakes." Over the years, numerous continuous improvement techniques have been developed. These techniques represent a system that has evolved from a basic concept of quality or process improvement, or both, in order to reduce losses, simplify the production line, and improve the quality of the business in general.

This work consists of two parts, in this part I present the essence and the attributes of the continuous improvement, and in the second part I present a synthesis of the continuous improvement trends applied in various business environments. In these business environments, specific methods and techniques that belong to the Kaizen strategy have been successfully applied, such as: Lean, Six Sigma, Balanced Scorecard, Poka-Yoke, JIT, 5S and Kanban.

*Keywords:* management; quality; improvement; performance; techniques; business.

---

### 1. Introduction

Improving business processes in business management theory and practice represents an alternative, compared to business reengineering theory and practice. A company's strategic management can choose this alternative in order to obtain performance and achieve business excellence. Even more, in practice within a company, business redesign processes can be implemented, which can then be sustained and maintained by applying processes that are based on continuous improvement strategies.

Basic concepts, methods, strategies and techniques for improving quality and business processes have their origins in Japanese management approaches, based on the Kaizen philosophy, which essentially means continuous improvement. The Japanese philosophy is on the principle of progressing and gaining performance on a continuous, permanent basis, in small steps. This kind of thinking is called Kaizen. KAI = change; ZEN = good, for the better (<http://www.thetoyotasystem.com>).

Below I will present some of the main ideas of this philosophy taken from specialty literature, as well as a series of Japanese management techniques applied for increasing the quality of the products manufactured, especially the ones in the automotive industry.

Managing strategies based on the Kaizen philosophy has developed in Japan between 1950-1980, and this term was formally used in management by Japanese professor Masaaki Imai, who founded the Kaizen Institute in America in 1985 to support US companies facing the low-quality product crisis. Subsequently, in 1986 he published the book "Kaizen: The Key to Japan's Competitive Success" (Masaaki Imai, <http://www.kaizen-competitivy.ro>), which had an extraordinary success being translated into over 14 languages and published in over 30 countries. Masaaki Imai is the initiator of the Kaizen concept in Japanese management through the way thinking, speaking and doing, considered one of the leaders of the quality movement.

---

\* Corresponding author. Tel.: +40722781313;  
E-mail address: ghicajanumihaela@yahoo.com

Here is what Masaaki Imai said in his reference book: By definition, Kaizen means continuous improvement involving everyone without spending too much money (Masaaki Imai, <http://www.kaizen-competitvity.ro>), (<http://www.qualitydigest.com>, An Interview with Masaaki Imai, 1997) and that the implementation of the Kaizen principles incorporates TQM (Total Quality Management). Included here are all methods and techniques known in the specialty literature about quality management: methods to reduce defects to zero, reduce the costs, improve response times in the supply or customer JIT, TPM specific techniques - Total Productive Maintenance, "3S" and "5S" techniques or suggestions, etc. All these techniques, as well as others, are described step by step in another Masaaki Imai publication "Gamba Kaizen, A commonsense approach to a continuous improvement strategy" <http://pmworldjournal.net/>, Masaaki I., (2012) (2012 second edition). Gemba means the workplace where all the action takes place. In this book, the author points out the importance of Gemba Kaizen - continuous improvement of the workplace, where things are done. This principle can even become a lifestyle, and if it is applied correctly, excellent results can be achieved in quality and not only.

## **2. Definitions**

Starting from Professor Imai's considerations, we understand through Kaizen - the process of continuous improvement for small increases that makes the process more efficient, effective, controlled and adaptable. Improvements are usually made without some sophisticated technique or expensive equipment. Improvement is done with the mind, not with money. The concept is based on simplification by dividing the complex process into smaller processes and then by improvement. By applying Kaizen-based methods to continuous improvement, process losses are eliminated through significant improvement, systematically using continuous observation and statistical data, continuously changing the tools and techniques used. Exceptional financial results can be obtained if the workers are also associated with these principles, which through training become more conscious and disciplined.

A definition that captures the essence of the improvement of this business process is: "It is a business process that allows organizing and managing product development, operations, relationships with suppliers and customers, that requires less human effort, less space, less capital and less time in order to produce higher quality products for well-identified customers, all these being in comparison with mass production systems" (Nicolescu, 1997)

Continuous improvement can be described as a culture based on the optimization of all systems and processes in an organization by gradually and continuously eliminating the losses or the waste.

Continuous improvement is a philosophy that Deming simply described as "Improving initiatives that increase success and reduce mistakes" (Juergensen, 2000: 3).

According to A.V. Todoruț and V.S.Tselentis, "continuous improvement is not only an important principle of quality management, but also an essential condition for the survival of organizations in a competitive environment" (Todoruț and Tselentis, 2011).

Although the term Kaizen is often considered to be the synonym of continuous improvement, Masaaki Imai asserts the existence of at least three types of Kaizen:

- Kaizen oriented on organization management
- Kaizen oriented on a group of people within the organization
- Kaizen oriented on an individual within the organization

Organizational management-oriented Kaizen is considered to be the most important, as it focuses on the company's strategy and it involves everyone in the company.

The group-oriented Kaizen in the organization is represented by Quality Circles that require the workers to form a team or circle in order to identify and solve the problems encountered in their daily activity without any interference with the company's management.

The Individual-oriented Kaizen in the organization is derived from a "top-down approach" in which workers provide recommendations on the issues they face. This theory has been successful in Japanese industries, given the fact that the employee works in the given ecosystem and knows the best solution to the problem. Some industries even have programs that want to stimulate workers, encouraging them to focus on problematic areas and find solutions for them in return for a reward.

## **3. Objectives of continuous improvement processes**

These Japanese management methods and techniques were initially implemented and developed in production management, with improvements and goals being pursued:

- the maximization kind: on increasing product quality, safety and working conditions, increasing the existing capacity of utilization; in productivity growth, stock management, compliance with standards, and flexibility in production processes.
- the minimization kind: reducing manufacturing costs; in reducing manufacturing time, time cycle, or production time; in reducing space costs, in reducing production accidents that cause loss; in minimizing: manipulation of materials, distances, efforts, storage, use, etc.

The most important principle of Japanese management techniques, compared to the classical management style in which solutions come from top to bottom - from manager to the cleaning woman or security guardian - solutions come back from bottom to top, that is from employees (gemba) to the manager. Employees have an essential role in the company. The general idea is that everyone is able to find solutions to improve the individual working process or the business process.

Improving product quality has become a top priority of the strategic management of a company or business. Quality management can be defined, from J.M. Juran's perspective, as "quality planning, quality control and quality improvement" (Ionică A., 2009:19).

On every Romanian company operates a multitude of factors that offer opportunities to be exploited, or which, on the contrary, generate restrictions that are need to be mitigated or eliminated. The factors that determine the need for sustained improvement in an enterprise's quality management can be both internal and external factors. These factors influence the activity of the organization directly or indirectly, causing changes of various natures and amplitudes. These changes can refer to the permanent adaptation to market requirements - to customer requirements first and to the attitude of the company in relation to suppliers, collaborators, and especially decisions and strategies taken in relation to competition. Here are some general factors:

- a first factor is the development of knowledge, generated by: the informational "explosion" that characterizes the current period;
- permanent training and improvement of the staff, becoming a strategic resource of the enterprise.
- increasing "immaterial" investment, with a tendency to equate the material investments.
- another factor that generates significant changes in the organization's environment is technical and economic progress.
- fast and substantial changes in products and services;
- essential changes in the company's management and economy;
- manifestation of a new attitude of the human factor towards some values, regarding the enterprise
- the emergence and consolidation of new values, like social equality, consumer protection, environmental protection
- a last factor is the internationalization of economies;

Among the basic objectives of improvement in quality management are (C. Oprean, 2008, pp. 68-69): Increasing the customer satisfaction; cost reduction; increasing the quality, increasing competitiveness, increasing productivity and profitability.

#### 4. The essence and attributes of continuous improvement processes

Koan Zen (Japanese philosopher) wrote, "If you do not understand, nothing changes" Starting from this principle, the goal is to learn Japanese quality, considering that "Enthusiasm is not enough - you need knowledge too" - "Knowledge is not enough - you need in-depth knowledge." A Chinese wiseman, Confucius, once said, "Knowing without acting does not mean true knowledge.; considering these lessons, as well as Professor Imai's viewpoints, we understand through Kaizen - the process of continuous improvement, gradually with small steps and increments, which makes the process more efficient, effective, controlled and adaptable.

Table 1. General features and attributes of continuous improvement processes

General feature of Kaizen improvement processes	Kaizen philosophy attributes
- gradual and continuous improvements, in small but fast steps	-Simplification or Division – simplified thinking, dividing the business process analysis
- the entire staff is participating, from director to simple employees (sometimes the best ideas come from those involved in the workplace – gemba)	-Continuous improvement – achieving sustained performance
- change and improvements are done through thinking, without costing too much	-Small growths – getting gradual results, step by step
- organization, perseverance and rigor in the working process	-Process – business process or work processes
- increased added value to the client and tracking the increase in his satisfaction	
- responsibility and discipline in the workplace; - diversity of methods, techniques and alternatives to applying them	
-the indicators are: efficiency(cost/benefit), effectiveness(object achieved in time), high quality, satisfied customers.	

Improvements are usually made without sophisticated technique or expensive equipment. Improvement is done with the mind, not with money. The concept is based on simplification by dividing the complex process into smaller processes and then by improvement. By applying the Kaizen-based methods, process losses are eliminated by significantly improving the process, systematically using continuous observation and statistical data, continuously changing the tools and techniques used. Exceptional financial results can be obtained if these principles are also associated with the workforce, who, through engagement and involvement, becomes more conscious and disciplined.

Table 2. Characteristics of continuous improvement processes

Characteristics	Improving business processes
1. The origin of the term	Japanese
2. The base principle	Continuous improvement of an existing process
3. Keywords (key concepts)	Simplification of thinking and acting; Continuous improvement; Results in small steps Business or industrial processes
4. Purpose	Performance, efficiency, efficacy
5. Participants	All those involved: workers, engineers, managers
6. Implementation time	It never ends, the processes can always be improved
7. Costs	Very low costs. One of the principles is that <i>"improvement is done with the mind, not with money"</i> .
8. Base methods	Methods of organizing continuous process flows: Just-in-time JIT, Taguchi method, KANBAN, HEIJUNKA, Bucket Brigades, JIDOKA Methods to reduce manufacturing change time: SMED method (Single Minute Exchange of Die), Total Productive Maintenance (TPM); Specific methods for controlling the processes: Six SIGMA, SPC Methods of analyzing and improving the processes: VSM Method (Value Stream Mapping) Methods for organizing the workplace: the method of 3S and 5S ( suggestion systems) Methods of excellence for continuous process improvement: the Deming method (PDCA Cycle), Juran, EFQM of Excellence, Baldrige of Excellence Methods to reduce costs and faults: Poka Yoke
9. Advantages	Low costs in general
10. Limitations	Results take time ( done in small steps) Perseverance and rigor, daily efforts

## 5. Conclusions

In this paper I presented the theoretical foundations regarding the techniques for improving the quality and business processes, by the principles of the Japanese Kaizen philosophy and the thinking of Masaaki Imai, that have as keywords: division, simplicity, small steps, consistency, patience, loyalty, low costs, quality, work well done, processes. Initially the Japanese management methods and techniques have been applied to improve the maintenance of production, aiming targets relating to: increasing the product quality; in safety and working conditions; the increased use of existing capacity; increasing the productivity; inventory management; in compliance; the flexibility of production processes; in the reduction of manufacturing costs; reducing time manufacturing process, time cycle or the time of production; in reducing the cost of space; minimizing: material handling, distances, effort, disorder, storage, use, etc. In time, these principles were extended to all activities in a company from accounting, procurement, logistics, information systems, human resources in all business processes.

## References

- Imai, M., *Kaizen: Cheia către succesul competitiv al Japoniei*, Ed. Prioritet, (2004).
- Ionică, A., *Managementul calității*, Editura Universitas, Petroșani, (2009).
- Juergensen, T., *Continuous Improvement: Mindsets, Capability, Process, Tools and Results*, (2000), accessed on <https://globaljournals.org>.
- Kaizen, Continuous Improvement*, Toyota Kaizen, (2009), accessed on <http://www.thetoyotasystem.com>.
- Masaaki, I., *Gamba Kaizen A commonsense approach to a continuous improvement strategy*, Publisher: McGraw-Hill, (2012).
- Mayle, D., *Managing inovation and change*, Third edition, (2006), accessed on <https://globaljournals.org>.
- Nicolescu, O., *Management comparat*, Editura Economică, București, (1997).
- Todoruț, A. V., Tselentis, V.S., *Îmbunătățirea Continuă A Performanțelor Organizațiilor Prin Benchmarking Intern*, Analele Universității "Constantin Brâncuși" din Târgu Jiu, Seria Litere și Științe Sociale, Nr.2, (2011).  
<http://pmworldjournal.net>  
<http://www.kaizen-competitivity.ro>  
<http://www.qualitydigest.com>, *An Interview with Masaaki Imai*, (1997).  
<https://ro.kaizen.com/despre-noi/definiia-kaizen.html>

## Techniques To Continually Improve Business Quality And Performance (II)

Ghicajanu Mihaela<sup>a\*</sup>

<sup>a</sup>*University of Petroșani, Petroșani, Romania*

---

### Abstract

Continuous improvement processes, based on Japanese management principles, organizational culture, or even their lifestyle, can be a way of organizing and managing business on principles of efficiency and efficacy. In the first part of the paper I presented the theoretical foundations regarding the processes of improvement in quality management and business management regarding: the concepts, objectives, characteristics and base principles of continuous business improvement processes - based on the Japanese Kaizen philosophy. In this part I present a synthesis of the continuous improvement trends applied in various business environments. In these business environments, specific methods and techniques that belong to the Kaizen strategy have been successfully applied, such as Lean, Six Sigma, Balanced Scorecard, Poka-Yoke, JIT, 5S and Kanban.

*Keywords:* management; quality; improvement; performance; techniques; business.

---

### 1. Continuous Improvement Techniques

Continuous improvement techniques have evolved from traditional factories with systems primary focused on production lines, reducing losses and improving the quality of the finished product, to hybrid techniques that focus on all aspects of the organization. Continuous improvement techniques aim at a wide range of organizational aspects and offer a variety of benefits, most of which are measurable in terms of quality, efficiency and speed (quality, cost, time).

The applicability of continuous improvement techniques within the different types of organizations has been widespread in recent years due to specialized firms and specialists in this field (providing advice, implementation assistance, training courses etc.). Over the years, many techniques for continuous improvement have been developed and they have been recognized as having some great contribution to: improving the products and processes of organizations; to increase efficiency and increase economic performance in industry, especially those related to production management and quality management. These techniques represent a system that evolved from a basic concept of quality or process improvement, or both, in order to reduce losses, simplify the production line, and improve quality. They were developed when there appeared a need for them, and the best known of these are: Lean Production, Six Sigma, Balance Scorecard and JIT.

### 2. Lean Production

#### 2.1 Lean History and Description of the Technique

Henry Ford systematized Lean Production in the 19<sup>th</sup> century, when he implemented the concept of mass production within his factories. The term Lean Manufacturing was introduced by James Womack in the book "The Machine that Changed the World: The Story of Lean Manufacturing". However, it is said that Toyota Motor Company in Japan has developed Lean's type modern thinking, also known as the Toyota Production System. Lean type production is a systematic approach to identify and eliminate losses through continuous improvement by pursuing to attract customers through products that aim to perfection. Lean production includes practices such as JIT (Just in Time), cellular manufacturing and work teams, (Shah and Ward, 2003). The elimination of losses is the core of Lean production, and

---

\* Corresponding author. Tel.: +40722781313;  
E-mail address: ghicajanumihaela@yahoo.com

the goal is to eliminate losses on each part of production, including customer relationships, product design, supply networks, and production management. Examples of losses include human effort, inventory management, time for product development and storage. The ultimate goal is to become very receptive to consumer demands, producing high quality products in the most economical and efficient way possible. Usually, the transition to a Lean environment does not occur instantly. The mentality of continuous improvement must reach the general goals of the enterprise. The results of Lean type production are the ability of the enterprise to learn. According to Lean philosophy, mistakes are generally not repeated because they are exactly what is required to be eliminated.

## 2.2 Implementing Lean

Lean production can be applied to organizations that pursue a move away from traditional manufacturing vision and invest less in storage, reduce labor costs and speed up manufacturing processes. The basic ideology underlying Lean is to minimize losses and develop skills to change. The principles of implementing Lean thinking are: Specifying the value for each family of products, from the point of view of the final customer; Identifying the activities within the value stream of each family of products, eliminating as much as possible the ones that generate losses; Sorting the value-making activities in a clearly defined succession(stream) of steps, so that the product reaches the final client through a more continuous process, without too many interruptions, turns, stops and intermediary expectations; Once the value stream has been established and entered, any internal or external client can apply the “pull” type system in order to “pull” the product directly from the producer when he wishes, instead of placing the product on the market; Once the value, the identified activities of value creation, those that generate the eliminated loss, the stream of value specified and introduced have been established, they can move on to operationalize and perfect the process, until it reaches and optimal level, in which the added value is maximal and most of the losses are eliminated.

**Implementation Costs.** The cost of implementation depends on a number of factors such as: the size of the organization, the level of Lean technology the enterprise wants to adopt, and the available resources. Costs can escalate if a restructuring of the organization is required.

**Implementation Period.** The implementation of Lean Production from scratch in an organization will also depend on the size of the organization and its objectives, but also on its resources if internal human resources are to be trained through external consultants or training. The duration of implementation time in a large organization may reach even half a year.

## 2.3. Examples of companies that have applied the Lean technique

Table 1. Companies that have used the Lean Technique

Companies that have implemented Lean	Romanian companies that have implemented Lean
<i>The Boeing Company</i>	<i>Continental</i>
<i>Yamaha Electronics</i>	<i>Totalgaz Industrie</i>
<i>Fujitsu Component</i>	<i>Cersanit România</i>
<i>Bosch Braking Systems</i>	<i>OMCO</i>
<i>BASF Group</i>	<i>Dacia Mioveni</i>
<i>Parker Aerospace</i>	<i>Ford Craiova</i>

Table 2. Companies that provide Lean Consulting services

LEAN Consulting Companies	Romanian Lean Consulting Companies
<i>TMB Consulting</i>	<i>ALFRA Consulting</i>
<i>Simpler</i>	<i>Genium Trening and Consulting</i>
<i>Catalyst Connection</i>	<i>Enviso</i>
<i>Lean Plus</i>	
<i>AEM Consulting</i>	
<i>Manufacturing Success Consulting</i>	
<i>Granite Bay Consulting</i>	

Tools required for Lean implementation: 5S, TPS tools, and those responsible with the implementation must have knowledge about Lean philosophy and experience with Lean tools like: Kanban, 5S, Poke-Yoke and others.

## 3. Six Sigma

### 3.1. Six Sigma History and Technique's Description

Six Sigma has its origins after Lean Production evolution, when Motorola developed a program called Six Sigma designed to achieve the goal of improving by a hundred times in 5 years. And it succeeded in such a way that the Six Sigma pioneers gained fabulous confidence in their product and delivered to customers without any prior control of the product. Six Sigma starts up as a means of measuring process quality using Statistical Process Control (SPC). The minimization of defects at a level close to zero was the basis for the methodology. Six Sigma has evolved into a much wider terminology that also represents a major opportunity to reduce costs. Since 1988, the impact on Six Sigma over the improvement of business processes has been so significant that today it is widely used by many top organizations.



Six Sigma has the ability to produce dramatic, measurable changes, reducing the cost and cycle time while improving product reliability, increasing consumer satisfaction, and delivering quality measurements that can be used throughout the organization, not just in the production department but also in design, administration and service areas.

Six Sigma is defined as a management technique that aims to improve business processes to create and deliver near perfect products and services (<http://www.trilex.ro/Metodologii/six-sigma-DMAIC.htm>).

It is defined by Pande as "a comprehensive and flexible system used to achieve, maintain and maximize business success. Six Sigma is driven by an understanding of customer needs, disciplined use of facts, statistical analysis, and careful management, improvement, and reinvention of business processes." (Peter Pande and Robert Neuman, 2000).

This technique, as mentioned above, is based on a statistical control process (SPC), which uses quantitative and graphical techniques to reduce the variance of assigned and variable measures of predetermined boundaries. The goal is set for a particular or variable part, along with the acceptable minimum and maximum limits where measures may be erroneous (standard deviation), and processes can be controlled using diagrams.

### 3.2. Six Sigma Implementation

**Implementation Costs.** The cost of implementing Six Sigma depends on the following major factors: The size of the organization (number of employees, its location); The existence of systems for improvement in the organization; Internal or external resources requiring training or employment;

**The optimal time for implementation.** The implementation period of Six Sigma is one of the most important factors for an organization and it depends on the following factors: The size of the organization (number of employees, its location); The existence of improvement systems in the organization; Commitment of top managers. The lack of this factor can lead to delayed implementation by not releasing the necessary funds and resources.

**Duration of implementation.** The entire implementation process in a medium-sized organization (500-1000 employees) can take between 6 months and 24 months, and for a large-scale organization (with over 1000 employees), implementation can take from 6 months to something more than 24 months.

### 3.3. Examples of companies that have applied Six Sigma Technique

Table 3. Companies that use Six Sigma

Companies that have implemented Six Sigma	Romanian companies that have implemented Six Sigma
<i>General Electric Company</i>	<i>Xerox Romania</i>
<i>Motorola Inc</i>	<i>Dacia Mioveni</i>
<i>The Boeing Company</i>	<i>Ford Craiova</i>
<i>NASA</i>	
<i>Honeywell International Inc.</i>	

Table 4. Companies that provide Six Sigma Consulting services

Six Sigma Consulting Companies	Romanian Six Sigma Consulting Companies
<i>Mulbury Consulting Limited</i>	<i>Six Sigma Consult SRL</i>
<i>Catalyst Consulting Limited</i>	<i>Enviso</i>
<i>The Athon Group</i>	<i>IGC Integrated Consulting Group</i>
<i>Ketch Consulting</i>	<i>Ascendis</i>
<i>Motorola University</i>	<i>SGS Group</i>

Regarding the duration of implementation, a small organization can usually complete the initial implementation model in a period of 4-6 weeks, compared to 12 to 14 weeks in large organizations.

Therefore, the fundamental idea of Six Sigma technology is that if the performance is improved, then the quality, capacity, time cycle, inventory levels, and other key factors such as loss reduction, energy sources, and environmental performance will also improve. Therefore, when these factors are improved, both sides gain, both the supplier and the customer experience greater satisfaction in business transactions.

## 4. Balanced Scorecard (BSC)

### 4.1. History and Description of the Balance Scorecard Technique

The Balance Scorecard technique was introduced to the world in 1990 and since then it has had a major impact on how organizations carry out their business. The Balanced Scorecard defines exactly what management wants to achieve when it comes to performance. It is a concept that allows balanced strategic planning at the level of an entire organization or its unit component. It is a system of management and optimization of the implementation of an organization's strategy, which allows it to achieve accelerated growth in operational performance and achievement of defined strategic objectives. Therefore, this technique can be used to translate the mission of the organization and the visions established in a set of objectives and performance measures.

"The Balanced Scorecard concept is a strategic planning and management system widely used in business and industrial organizations, in the public system and non-profit organizations around the world to align the activities to the organization's vision and strategy, improving internal and external communication and monitoring the organization's performance in order to achieve the strategic goals" (Balanced Scorecard Institute, <https://www.balancedscorecard.org/>).

The system consists of 4 processes: translating the vision into operational objectives; explaining the vision and linking it to individual performance; business planning; feedback, learning and strategy adjustment based on evolution.

It is generally used to: clarify the business strategy; keep everyone informed about the business strategy; it relates the organization's intentions within the annual budget; makes space for organizational change; increase acceptance of the vision and mission of the company throughout the organization.

The companies that use Balanced Scorecard are able to achieve their goals if the Balanced Scorecard is transformed from a measurement system into a management system. This technique covers the deficiency that many organizations have, namely when a strategy feedback is to be received. The implementation of a long-term strategy becomes a primary goal and a focus of the organization built around the Balanced Scorecard.

#### 4.2. Implementation steps

Implementation of the system is only possible in relation to defining the vision, strategic objectives and general strategy of the firm. Determination of partial and derived strategies, setting of secondary and individual objectives, as well as establishing a hierarchy and prioritization is necessary to accompany the implementation process, (Ștefănescu and Silivestru, 2012:25). Implementation of the Balanced Scorecard involves 2 phases, the planning phase and the development phase reflected in the following steps. Tools used to implement the Balanced Scorecard are: Brainstorming, Six Sigma tools, Lean Instruments.

#### 4.3. Examples of companies that have applied the technique

Table 5. Companies that use Balanced Scorecard

Companies that have implemented BSC	Romanian companies that have implemented BSC
<i>Motorola</i>	<i>Rompetrol</i>
<i>Royal Air Force</i>	<i>Bitdefender</i>
<i>Kraft Food</i>	<i>P&amp;G</i>
<i>Marriott</i>	<i>Guvernul României</i>
<i>Hilton</i>	<i>Transelectrica</i>
<i>UPS</i>	<i>Deloitte</i>
<i>Siemens</i>	<i>ING Bank</i>
<i>Cisco</i>	<i>Euralis</i>

Table 6. Companies that offer Balanced Scorecard consulting services

Balanced Scorecard Consulting Companies	Romanian Balanced Scorecard Consulting Companies
<i>Balanced Scorecard Institute</i>	<i>Ensign Management Consulting</i>
<i>Hudson Associates Consulting Inc</i>	<i>Strategic Systems Consulting</i>
<i>Value Creation Group</i>	<i>Codecs România</i>
<i>Crescent Consulting</i>	
<i>Balanced Scorecard Collaborative Inc</i>	

### 5. Conclusions

In the last decades, comprehensive methods and techniques to achieve continuous improvement have evolved. The principles of these methods and techniques have begun to be applied not only in production activities but in all the activities within a company. The Japanese management techniques have become more and more present in Western and European business environments, based on the principle that: improvements that are constantly, persistently and speedily achieved, lead to results that are obtained over time in terms of quality, profits and customer satisfaction.

### References

- Pande, P., Neuman, R., Cavanagh, R., *The Six Sigma Way, How GE, Motorola And Other Top Companies Are Honing Their Performance*, (2000).
- Shah, R., Ward, P.T., *Lean manufacturing: context, practice bundles, and performance*, (2003).
- Ștefănescu, D., Silivestru, M., *Balanced Scorecard - Instrument of strategic planning*, Revista Română de Statistică nr. 2, (2012).
- <https://www.balancedscorecard.org/>, about Balanced Scorecard Institute
- <http://www.ebalancedscorecard.ro/pages/conceptul-bsc/>; <http://www.ensight.ro/newsletter/no05/articol9.htm>
- <http://www.immromania.ro/tehnici-lean-aplicate-cu-succes-in-peste-150-de-companii-din-romania--7565.htm>
- <http://www.trilex.ro/Metodologii/six-sigma-DMAIC.htm>
- [https://globaljournals.org/GJRE\\_Volume12/6-Lean-Sigma-A-Road-to-Success-A-Perspective.pdf](https://globaljournals.org/GJRE_Volume12/6-Lean-Sigma-A-Road-to-Success-A-Perspective.pdf)
- <https://leanromania.wordpress.com/2008/05/22/drumul-lean-catre-intreprinderea-performanta/>
- <https://www.isixsigma.com/new-to-six-sigma/sigma-level/how-calculate-process-sigma>

# Quality Supplier Response to Industrial Procurement Behavior on the South East European Metal Distribution Market

Székely Szilárd\*, Adriana Benedek, Lucian-Ionel Cioca

*Lucian Blaga University of Sibiu, Bdul Victoriei, no. 10, Sibiu, 550024, Romania*

---

## Abstract

Industrial marketing presents a list of peculiarities which differs from the “classic marketing” (the business-to-consumer). We can observe increased interactivity between selling teams and DMU (decision making units or buying centers). A good analyses and proper understanding of DMU’s behavior and needs give the opportunity to industrial supplier companies to offer a quality response and to obtain better commercial and financial results for mutual benefits, sustainable development and long-term success.

This paper presents multidisciplinary characteristics by mixing different approaches, solutions from industrial marketing, organizational (customer) behavior, sales management, management and digital marketing.

In this paper we shall analyze these peculiarities and processes by secondary market data analyses, professional in-depth interviews with members of DMU’s and selling teams from different countries, direct behavior observations from the market (industrial exhibitions or negotiations between sales representatives and buyers). One of the key area of the paper shall be the situation of the presented peculiarities on the (metal) semi-finished products on Romanian and South East European markets, in the era of digital marketing.

In nowadays industrial marketing, digital and traditional marketing concepts, instruments and tools are converging. The activity of sales forces are sustained by adapted marketing mix, digital tools and use of web based technology, strong long-term relations, automated processes, targeted communication to buying centers members, useful marketing and technical information, and customized services for key account partners.

Keywords: industrial procurement behavior, organizational buying behavior, buying center DMU, industrial marketing, semi-finished product marketing

---

## 1. Main features of industrial marketing

Industrial marketing or business-to-business marketing is many times treated like a down-graded version of the “classical” marketing, the business-to-consumer or the consumer’s goods marketing. “Marketing has its roots in understanding consumers, and because we are all consumers and business-to-consumer marketing (from communication to effective selling has more visibility) it has become altogether too easy to concentrate on using consumer-based examples and theories when discussing marketing concepts. However, business markets are far larger: businesses buy and sell more goods than do consumers, and the transactions that take place between organizations have a greater impact on the economy and on the welfare of people than do the transactions between businesses and consumers.” (Zimmerman A., Blythe J., 2004). However, B2C marketing has high visibility, starting from commercials in mainstream media channels to shopping malls, B2B marketing is most of the time more discreet, is taking place behind closed doors, at business meetings and nowadays online. In order to develop efficient industrial marketing strategies first we have to understand the similarities and differences between marketing to consumers and marketing to professional buyers from commercial or industrial organizations.

Continuing the parallel presentation of B2C and B2B, the first step is to understand our consumers, or in our case the industrial buyers (or as often called buying center or DMU – decision making unit). In order to be able to offer high quality services and to achieve sales or marketing targets our first duty is to deeply understand the way that our

---

\* \* Székely Szilárd Tel.: +40-740-210778;  
E-mail address: office@astiadvertising.ro

costumers acts in a procurement process. In the present paper we'll make some comparison between the two major types (final consumer and industrial) of marketing and procurement, but the main focus will be on industrial markets and especially on the semi-finished metal products market in Romania and South East Europe.

The first issue that we have to focus on is the main purpose of companies acting on B2B markets: they have as main goal the profit and wealth growth. Company's interest is most of the time openly assumed based on rational decisions, also personal interactions and relations, reciprocal dependency at least for medium term are usual on this market. (Torocsik, M., 2007). The first impression when we talk about industrial marketing is that heavy equipment, production halls or even high-technology is involved. In this order marketing experts from this field need to have solid technical and economical knowledge.

David Ford focuses on three main directions: the features of the relations with suppliers, the volume and organizational infrastructure and the measure of relying on existing suppliers. (Ford, 2003). In his opinion, the most important task of an expert in business marketing is to give a quality support to the procurement process of the buyers.

One of the most accepted description of industrial buying features is given by Kotler. But first, we need to clarify the concept of organizational buying or procurement. Kotler refers to the Webster and Wind when defines the organizational buying as "the decision-making process by which formal organizations establish the need for purchased products and services and identify, evaluate, and choose among alternative brands and suppliers" (Kotler, Ph., 2002). So, a quality supplier response needs to follow the path described in this definition.

In the next table we try to offer a list of the most important peculiarities of industrial markets, based on the works of Zimmerman and Blyth (2004), Torocsik (1997 and 2007), Jozsa (2005), Kotler (2006) and others, which we adapted to the market of semi – finished metal products in Romania and South East Europe:

Table 1. Industrial markets' peculiarities adaptation on the semi-finished metal products' market

<b>Industrial marketing features</b>	<b>How it appears of semi-finished metal market</b>
Limited number of actors, market concentration	Less than 20 important producers and less than 100 resellers
Narrower customer base	From a few dozens to a few hundreds usual buyer
Derived and inflexible demand	Costumer market's demand influences, for ex. if people don't buy cars, on medium terms aluminum and steel sales decrease
Products are technically difficult to substitute	High quality products are important, but there are no big differences between products, complementary services do the difference
Importance of personal relations and sales force	Over 80% of sales are due to sales force and realized with long or medium term partners
Many sales visit (interaction) for one (first) transaction	For the first sale sales man pays many visit and changes lots of information through internet and phone
Internationally opened markets	International and multinational corporation appear on the market regularly as suppliers and customers, too
More formalized transactions	Transactions are based on price offers (request), contracts, orders, shipment documents, bank payment...
Additional services	Cutting to size, delivery routes, packaging, consultancy
Importance of buying centers or DMUs	(Design) engineers, plant managers, buyers, financial experts influence the decisions, at least at major negotiations
Many influencing factors on procurement	Product standards, price, reaction / delivery place and time, commercial credit, brand image, auxiliary services, relationship are also important
More rational decision	The above mentioned factors are quantified and weighted
Networking -clustering	In some subfields are important
Demassification	Every company has its needs and expectation-sometimes customization
Different segmentation	Segmentations by size, field of activity, volume of materials used, but also business style: willingness to risk, need for partnership and safety
Less end user info	Those who sales electrical, aluminum, steel semi-finished products don't really know in which way final costumers will use the product

For our paper the most interesting topic for the above list are those related to the behavior of the DMU's or buying centers: the importance of personal relations, more formalized transactions, more rational decision and many influencing factors on procurement.

## 2. Industrial procurement behavior (I.P.B. or O.B.B. organizational buying behavior)

Nowadays marketing experts and salesmen complain that consumers "behave in a strange way", "no one can understand what they want, how they make buying decisions". Understanding consumer's behavior, researching it, analyzing it became an important task of marketing departments. The same way that "classical" (consumer) marketing made the transition from production orientation trough product, then sales, and consumer focused marketing orientation till the actual societal marketing (Kotler, 2017), industrial marketing moved the focus from the product orientation to focus on the consumer behavior, in our case, the industrial buying (or procurement) behavior and relationship marketing. In the lack of dedicated space, we only mention a few concepts in this progress: the 4P (marketing mix: product, price, place and promotion) evolution to 7P (4P + physical evidence, process, people) or into 4C (consumers' needs, cost to satisfy, convenience, communication) etc. Or we can go further to the 4V concept, which focuses on the validity of the offer, the value, the venue and the vogue. One of the most interesting and complicated issue related to

consumer behavior analyses in industrial marketing is that industrial procurement is a **collective decision**, even if we can separate it into three levels:

- individual level – or interest;
- decision making units or buying center level;
- organizational level. (Torocsik, 2007).

Another aspect to clarify when discussing about industrial procurement behavior is that these companies use the procured goods for their business goals (Jozsa, 2005):

- users need the product (a machine, a tool) in the process of production of new products they sell to the market,
- buyers - producers, who build the goods into their own product (for ex. semi-finished metal bars for a car component). The US literature call them OEMs (Original Equipment Manufacturers),
- resellers – who don't use or change the products, they resell it in an unchanged form. Their customers are the previous two categories.

### 2.1. The process and participants to the industrial procurement

The process of decision making in industrial procurement is (similarly to individual or familial consumer behavior on consumer goods' market) is a multiple stage process. The number and the complexity of these stages vary influenced by many factors: the size of the company and the decision making units; the value of the acquisition; and the influence of the product (or service) on the activity and financial situation of the buyer company (from small spare parts to strategic industrial equipment or an ERP system). (Jozsa, 2005). Fill (2005) completes the ideas of Spekman, R.E. and Gronhaug, K. (1986) and identifies four groups of main influencing factors.

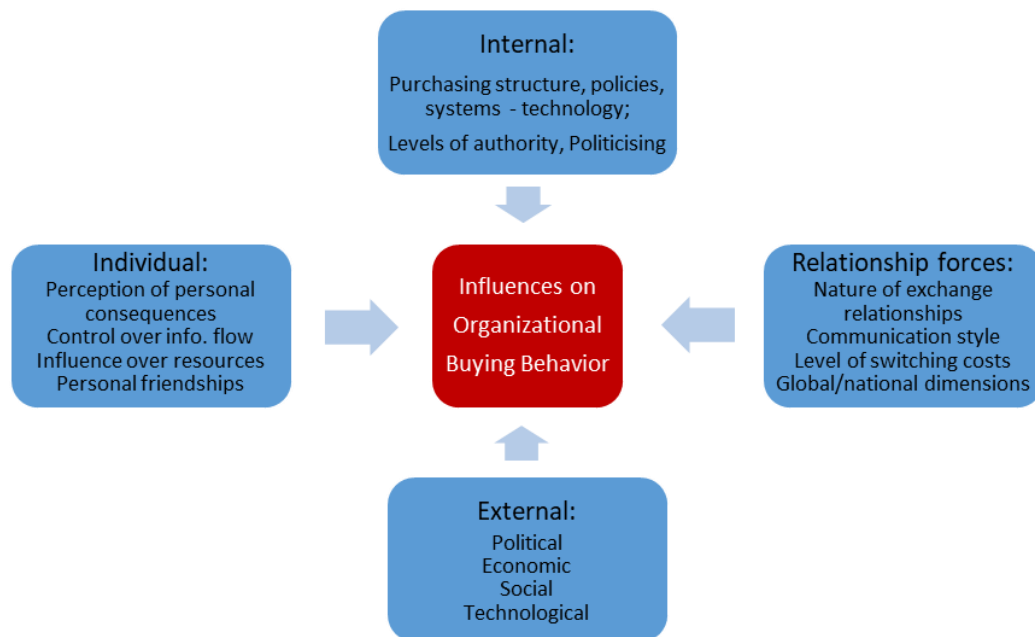


Fig. 1. Influences on O.B.B. (Organizational Buying Behavior) (adapted after Fill, 2005)

The classical stages of industrial procurement process are (Backhaus, 1997):

- identifying the problem, the need for a certain product, defining the value or volume needed to be procured
- searching for a solution, collecting product alternatives,
- assessing and comparing offer phase,
- negotiation – detailed discussion between seller and buyer (teams), comparison of offers (technical, financial, logistical and service aspects),
- decision making, order or contract signing,
- delivery stage, product using stage,
- additional stages: quality inspection, training, follow-up etc.

In case of complex products the offer, negotiation, decision making stages can have many other intermediate stages. Also the delivery and product using stage can suffer changes: testing, renegotiating, product – system development etc.

In present days, on the South East European metal distribution markets **sales force are still the dominating force**, but they became more and more **over-busy**, mostly because losing too much time and energy with small valued, transaction based selling, while not being able to properly serve the key account partners or focus on relationship marketing.

Cardozo (1980) found that industrial organizations tend towards one of two main strategies or directions in procurement. They are called the optimizers or satisfiers. The optimizers negotiate with a large number of potential suppliers and evaluate a list of proposals before selecting a supplier. The satisfiers prefer to have partnerships with familiar suppliers and signs contracts with the first company to fulfill the requested tasks.

In case of increased risks individual actions leave place to DMU-s, as Johnston and Lewin (1996) affirms.

The next question is, who is responsible for the above described process. As we already, shortly mentioned: the DMU (decision making unit) or Buying Center holds the responsibility for the whole project. This DMU is a complex team, with interesting models of functioning as you'll see in the next sub-chapter: DMU – Buying Center

Most of the researches, articles or educational resources focus on the group level, the decision making unit or the so called buying center. Probably the main reasons for it is that through analyzing DMU we can observe as well individual aspects and the same time with organizational features. The last 40 years, as industrial marketing reached a larger academic and industrial attention, many buyer behavior models were developed. We can distinguish partial and complex models. The partial models focus on analyzing one factor at one time, while the complex model aims to bring together all the main elements of organizational procurement behavior.

As Spekman and Gronhaug (1986) point out, the DMU is a 'vague construct that can reach across a number of different functional roles with any number of individuals participating or exerting influence at any one time'.

The dimensions and forms of Buying Centers are not stable. It can vary due to the complexity of the product to procure, the level of perceived risk in case of every decision taken by the organization. There is a need for special roles, because the procurement task is modified at every new procurement situation, (Bonoma, 1982).

Table 2. Procurement (buying) behavior models categories (adapted after Torocsik, 2007)

Partial models	Complex models
Buying center concept	Robinson Faris Wind – Buygrid model
Sub-division related to organizational power	Bonoma Zaltman Johnston
Sub-division related to reaction	Webster Wind
Focus on interactive communication	Sheth
	Choffray Lillien

### 3. Quality supplier response to the industrial procurement behavior

In these analyses we have to maintain focus on the basic principles on which companies activate: obtaining profit, sustainable development and increasing company's worth. So, **helping customer companies to obtain profit** by reducing acquisition (logistics, operational) costs and increasing sales are vital for suppliers.

The classical response to customers' needs in marketing was the **marketing mix**, or the 4P's: product policy, price policy, distribution or placement policy and promotion policy. And as the name suggest it is very important the proper mixing of these ingredients to a selected target (based on an STP strategy: segmentation, targeting and position). In industrial marketing some authors consider that the first two P's (product and price) have to be managed together as "offer policy": product and service range, prices, discounts on volume or value, payment conditions etc. Many times on metal markets the question „when to pay?“ is more important than „how much to pay?“.

The first aspect of analyzing seller-buyer interaction on industrial market are the relations between focusing on long-term relations versus individual transactions, and between focusing on individual customer versus on market segment, as you can see in the next figure. The study of organizational buying behavior needs to focus on developing and managing **inter-organizational relationships** on medium and long term. (Fill, 2004) The stronger the relations are the mutual benefits increase, including quality services are provided and both parties can be successful on long-term.

In industrial marketing many researchers affirm that relationship marketing is more important than the marketing mix. Knox (2000) suggests that there are three reasons why competitive advantage might be improved through **stronger relationships**. Systems cost reduction – cost savings from improved working practices: for ex. **improved order cycle times, reduced stock** and working capital, buyer centers already knows the products features, **delivery methods and time** etc. Increased effectiveness through innovation – as a relationship develops, more information is exchanged and suppliers become more willing to invest in the relationship (supplier holds on stock special semi-finished products for key accounts). Enabling technologies – electronic systems and communications help suppliers to **anticipate and understand the needs of their customers** (partner companies can set up common online systems for orders, payment etc. Suppliers become more able to evaluate the cost-effectiveness of their customer portfolios and to determine where to invest.



Fig. 2. Industrial market analyzed based on seller-buyer interaction (adapted after Jozsa et al., 2005)

Organizations work, wherever possible, to reduce uncertainty and risk. By working with others who are known and trusted, of whom the organization has direct experience, risk and uncertainty can be substantially reduced. So building relationship marketing approach is also a quality supplier response to industrial procurement behavior. Fill (2004)

It is vital for seller organizations to **identify members** of the buying center and to **target and refine their messages** to meet the needs of each member of the center, for ex. a design engineer needs information about the features of materials or semi-finished products, the logistical manager about the deliveries, the financial officer about price and payment methods etc. Fill (2004). Ronchetto et al. (1989) provide some insight into how influential members of a DMU might be recognized. Their research suggests that there are several criteria that indicate those members who have above average influence. In addition to those members who occupy particularly significant influential positions, they cite people who: work close to the organizational boundary; are near the center in terms of internal relations; has an active position in communication between the departments of customer firms; are connected directly to top management.

**Quality auxiliary services** are very important in many subfields, such as (cut to size) **service centers** for metal semi-finished products, **consultancy** related to use of products (including personal consultancy, or even online tutorial videos), **products presentation** workshops.

**Useful marketing and technical communication** at all time. This can be realized using the omni-channel approach, wherever the customer is looking for information (or product) the supplier needs to be there: Google Search by search engine optimization, web pages with text, infographic or video tutorial based frequently asked questions, e-mail, segmented – targeted newsletters, call centers, personal visits, even chat bots with artificial intelligence backup.

**Use of web based technology** – online technical and commercial communication, proper customer data base, CRM systems, EDI or ERP systems, B2B adapted e-commerce platforms, segmented and targeted newsletter communication etc. also increase the quality of supplier response to I.P.B. One of the first tools needs to be the use of search engine optimized web pages (for giving permission to customers to obtain information and contact suppliers), which are also filled up with valuable technical and commercial information and user friendly. Acquiring valuable data about customers and properly managing them (including CRM, ERP and on medium term big-data use) can increase the value of services provided to customers. A supplier needs to be everywhere where a (potential) customers is looking for information, products, services, advices (Fox, 2010). Organizations need to be sure that strategic relationships between suppliers and customers are protected and technology is used to complete long term partnership, not to jeopardize them, Fill (2005).

And finally, as Kotler (2017) suggested “technology convergence will ultimately lead to the **convergence between digital marketing and traditional marketing**. In a high-tech world, people long for high touch”. So, the same on the metal semi-finished products market, supplier needs to develop strong relationships with buyers using the personal high quality touch of sales force and also back-up from online (digital) technology. But regarding also the efficiency of serving markets sales force needs to focus personally on long term relations and key accounts while transaction type sales need to be automated. So, I propose a model with proportioned use of personal selling, the more important the customer and the relations are, the more personal involvement and customized services are necessary for a quality response to customers’ needs. The figure 1. presents the main influences and recommend supplier (seller) response.



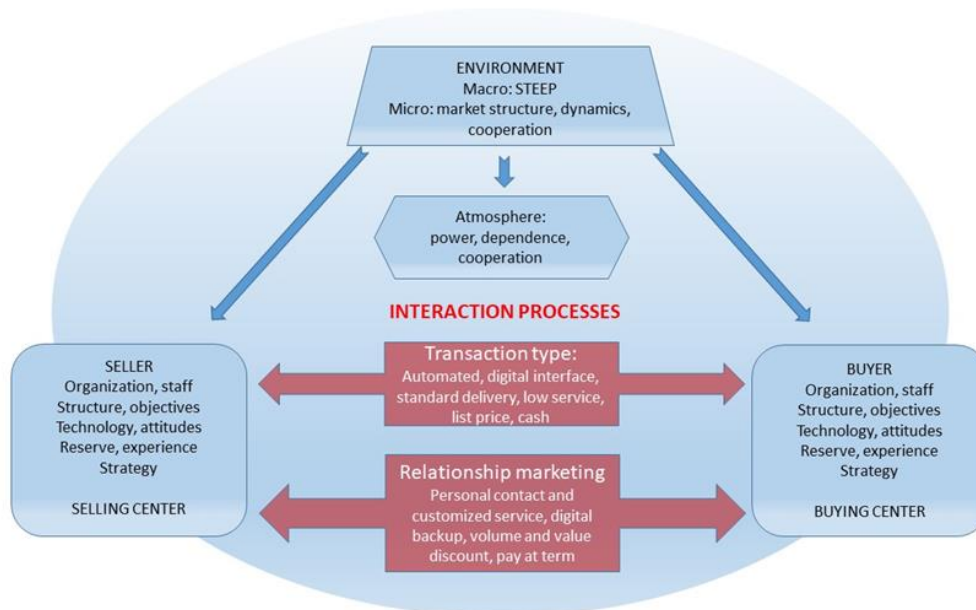


Fig. 3. Quality supplier response to industrial buying behavior in case of transaction versus relationship type interaction processes on industrial markets (Adapted after Turnbull – Valla, 1987 and personal researches)

In the case of transaction type selling the interactions need to be automated as much possible, standard, but quality delivery, list prices, without discounts and no payment at term. On the other hand, in case of long-term relations, with higher value of sales, selling center need to provide a more personal contact, customized services (which can be supported by business intelligence systems). Also volume and value discounts, and pay at term can increase the satisfaction of buying centers. The mutual benefits are the key to long term success.

## References

- Backhaus K., Koch, F.K. (1985) Behavioural Industrial Marketing Research in Germany and the United States-A Comparison, *Journal of Business Research*, Volume 13, Issue 5, October 1985, Pages 375-382
- Backhaus K., Lügger K., Koch M., (2010), The structure and evolution of business-to-business marketing: A citation and co-citation analysis, *Industrial Marketing Management* 40 (2011) 940–951
- Bonoma, T.V. (1982). 'Major sales: who really does the buying?', *Harvard Business Review* (May/June), p. 113
- Cardozo, R.N. (1980). 'Situational segmentation of industrial markets', *European Journal of Marketing*, 14, 5/6
- Fill C., (2005) *Business to business marketing, relationships, systems and communications*, Pearson Ed. Ltd, UK
- Ford D. (2003) *Business Marketing*, Editura KJK Kerszov, Budapesta
- Fox V., (2010), *Marketing in the age of Google*, John Wiley and Sons inc., New Jersey USA
- Jozsa L., Piskoti, Rekettye, Veres (2005). *Decision oriented marketing*, Editura KJK Kerszov Budapest
- Johnston, W.J. and Lewin, J.E. (1996). 'Organizational buyer behavior: towards an integrative framework', *Journal of Business Research*, 35, 1 (January), pp. 1–15.
- Kotler Ph., Kartajaya H., Setiawan I., (2017), *Marketing 4.0 -Moving from Traditional to Digital*, Wiley, N.J., USA
- Knox, S. (2000). 'Organisational buyer behaviour', in Cranfield School of Management (eds), *Marketing Management: A Relationship Marketing Perspective*, Basingstoke: Macmillan, pp. 62–76.
- Kotler. Ph., Keller K., (2006), *Marketing menedzsment*, Editura Akademiai, Budapesta
- Robinson P., Faris Ch. W., Yoram W., (1967), *Industrial buying and creative marketing*, Allyn and Bacon, Boston
- Ronchetto, J.R., Hutt, M.D. and Reingen, P.H. (1989). 'Embedded patterns in organisational buying systems', *Journal of Marketing*, 53 (October), pp. 51–62.
- Spekman, R.E. and Gronhaug, K. (1986). 'Conceptual and methodological issues in buying centre research', *European Journal of Marketing*, 20, 7, pp. 50–63
- Torocsik M. (2007) *Vasarloi magatartas*, Editura Akademiai, Budapesta
- Torocsik M. (1996). *Ipari marketing*, Editura Nemzeti Tankönyvkiado, Budapesta
- Webster F.E., Wind Y. (1972), *A General Model for Understanding Organizational Buying Behavior*, *Journal of Marketing* (American Marketing Association), Vol. 36, No. 2 (Apr., 1972), pp. 12-19
- Zimmerman A., Blythe j., (2013): *Business to business marketing management a global perspective*, II. Edition Routledge Taylor and Francis Group, New York, USA



## Innovative Method of Increasing the Quality of Management in Administration Using the Principles of Sharing Economy

Lucian Lupu-Dima<sup>a\*</sup>, Eduard Edelhauser<sup>a</sup>,  
Emilia Corina Corbu<sup>a</sup>, Amalia Furdui<sup>a</sup>

<sup>a</sup>University of Petrosani, Universitatii street, No. 20, Petrosani, 332006, Hunedoara

---

### Abstract

The increasing requirements of the local administrations, the challenges generated by the changes in the socio-economic environment, the technological progress, lead to the emergence of the difficult to manage situations given that sometimes the resources are scarce, the time of solving them is limited and even human resources are insufficient. In this paper we intend to show a model to be applied at local administration, proving its advantages, using the principles of sharing economy, this way aiming at coagulation of the capacities of an association of communities, in the interest of each individual.

Keywords: innovative; quality; management; IT; GIS; sharing economy;

---

### 1. Introduction

The improvement of the living conditions, the access to resources and to good quality services are desiderata that have become normality in modern society and they exist in all present and past government programs.

According to the current government program (Government) "There is no citizen who does not want a home with all the comfort (water, sewage, heat, electricity), who does not wish to be able to move safely and rapidly to work, ... " and "The answer is simple and at the same time very complex: the one who must take care of the needs of the citizen is the state by means of all its administrative structures."

The conclusion is obvious, the need to increase the quality of management in the administration is mandatory, no matter who governs it.

The methods of increasing the quality of management in the administration are diverse and we do not believe there is a unique solution, but they need to be adapted to the nowadays context and to the future perspectives. In accordance to this statement, observing these realities and understanding that the resources are limited, we try to prove the need of local administrations to use the sharing economy principles to perform in the work they must do.

### 2. Prerequisites of using the principles of sharing economy in administration

As Horton, John J., Zeckhauser, Richard J., Owing show in *"Using and Renting: Some Simple Economics of the Sharing Economy,"* the notion of renting of goods underwent a development, moving from the situation where the owners own assets which they rent, to that where the asset holders use them for their own good but also for renting (Horton). It is this development the one that led to the notion of *sharing economy*, and the benefits were mainly given by efficiency. This model, which has come to be a practice presented in almost all sectors of the economy, with a size of \$ 15 billion in 2013, is estimated to reach 335 billion in 2025 (Cakravathi)

---

\* Corresponding author. Tel.: +40722420401  
E-mail address: lucianlupu@upet.ro

### 1.1. Sharing economy a sustainable perspective

Currently *sharing economy* is practically present in all economic sectors, as can be seen in Figure no.1.

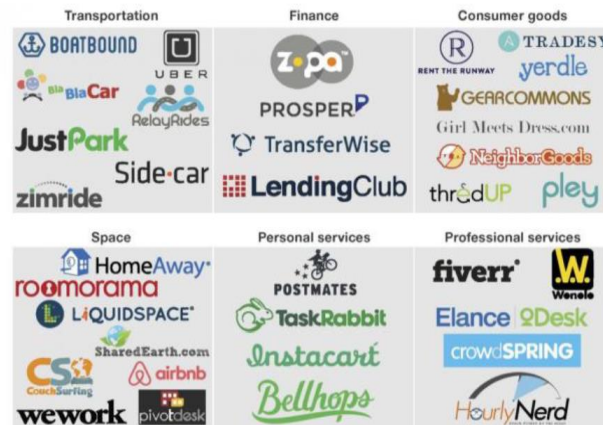


Figure 1 Example of sharing economy (Chakravathi)

The subject is attractive for all actors involved in the market of goods and services and even for researchers. Andreotti shows that in the Eurobarometer 2016 questionnaire is presented the information that says that most of all Europeans respondents are aware of the existence of sharing economy but only about 17% declare that they have directly used the sharing economy. The pace of development of the sharing economy is high, because of the benefits, but also of the digital tools capable of supporting such development. Figure 2 shows an evolution of the financial dimension by domains.

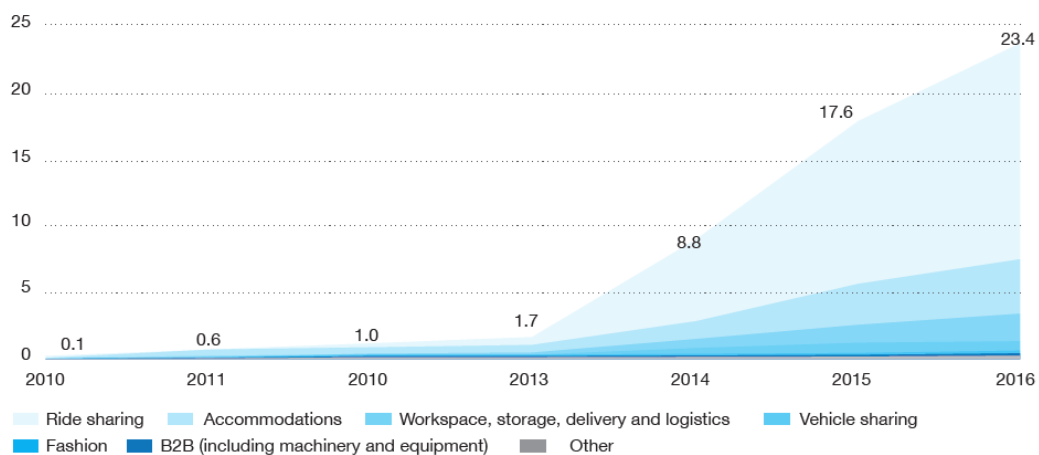


Figure 2 Evolution of financing the sharing economy on the domains (Future)

The advantages of sharing economy that offers attractiveness and viability are numerous and diverse being related to the customer's requirements. Thus, Uber through its rating system, offers marks of reputation that stimulate the provider while offering confidence to the customer (Codagnone). Airbnb, with its double rating system, stimulates the provider's attitude in relation with its customer (Andreotti). These arguments come as accompanying elements to what has already been clarified, starting from the possibility of renting, continuing with the need for a limited-term use and ending with the efficient possession of means.

The performed analyzes lead to a series of conclusions that show a sociodemographic stratification of sharing economy, proving unequivocally a link with digital stratification. Also, even if young users, higher-income users are more likely to use sharing economy, it is noticed that an analysis of sharing economy cannot be done in simple terms because it has influential factors and ongoing dynamics of digital platforms. Urban localization is also not a factor of influence (Andreotti). There are also significant implications regarding the component of the owners or of the future owners of goods who are to decide in accordance with the rental cost equilibrium (Horton).

Even if risks exist, such as the diminution of car sales, the increase of rents in some situation, as the case of Airbnb is now that is subjected to some interventions by some states where the listed properties are found, the efficiency of using goods, the rising of the consumption surplus, the high adaptability to the market needs, the customization of the offers and the coverage of the ignored market areas, lead to the conclusion of the viability of the sharing economy (Chakravathi).

## 1.2. Sharing economy in administration

In the group of examples in Figure 1 we cannot find city-halls, town-halls or other entities from the administration. However, does the local administration exist on the sharing market? Yes, it exists. The Future of Urban Development and Services Initiative at The World Economic Forum has conducted a study of 10 localities across the globe and a collaborative whitepaper from cities resulted: From Sharing to Sharing Economy, which shows how things are regarding this topic (Future).

In the opening word, one of the three speakers, Hazem Galal, Global Cities and Local Government Sector Leader, PwC, says that local administrations come to share the access to the municipal spaces and to other resources because of economic, social or environmental reasons. Local governments come to share their equipment, to collaborate to provide services to those targeted. (Future).

In the conducted study it was determined that the local administrations used to share the assets of the administrations, spaces and actives, services and competencies of the residents. As an example, a platform is created for goods, myTurn.com, that allows the trading of the offers of sharing. Regarding the spaces and the actives, for exemplification, the sharing allowed that through 596acres.org 200 locations to be transformed and 39 news community managed spaces to be created.

The state government in Alberta, Canada provides the framework and encourages municipalities from this state to collaborate with neighbors to work together to provide services by means of the Intermunicipal Collaboration Framework. The legal framework, with legislation that will come into force this year and will be effectively applied in 2020, is elaborated.

In Barcelona, through the "Program of Time and Caring Economy", it was made possible for an opportunity for people to help each other regarding daily tasks such as taking care of a sick child, reading books to the elderly, caring for domestic animals or plants, repairing things, or simply accompanying people on a walk, to be created.

The system functions as a time bank, the services rendered being considered as depositors, and citizens can redeem the time they invest for time from others to perform services for them. (Future).

## 2. Analysis of the need and availability of sharing economy in public administration in Romania

Although there is no public information in Romania confirming the use of sharing economy in public administration, there is a need and availability for use. To support this statement, I created a questionnaire by means of which we tried to analyze the state of digitization of spatial data, the future intentions regarding the digitization and the extension of the endeavor in the sense of the GIS implementation, endeavor that I submitted for completion at the ATU level in Hunedoara County.

We have collected information from 27 respondents, 11 cities and municipalities from 14, 15 villages from 55 of Hunedoara County. We have chosen to use this argument, because in the work paper "GIS, Integrated Solution, for Efficient Administration and Hunedoara County" (Jornea), published in 2017, we have shown the advantages of a GIS of such a scale.

### 2.1. The existing situation in Hunedoara County regarding spatial data

Romania, as part of the EU, is bound to implement the INSPIRE Directive, which is why it created a legislative framework registered in GO 4/2010 and in GD 579/2015. Consequently, at the level of each ATU, resources were allocated for the application of the legal requirements.

The question "At ATUs level, is initiated the procedure for the implementation of the requirements of the GO 4/2010 regarding the establishment of the National Infrastructure for Spatial Information (INIS) and of the GD 579/2015 regarding the establishment of the specific responsibilities of the public authorities, as well as of the technical structure for the implementation of spatial data themes and the approval of measures to share them?" had 24 responses as it can be seen in Figure 3.

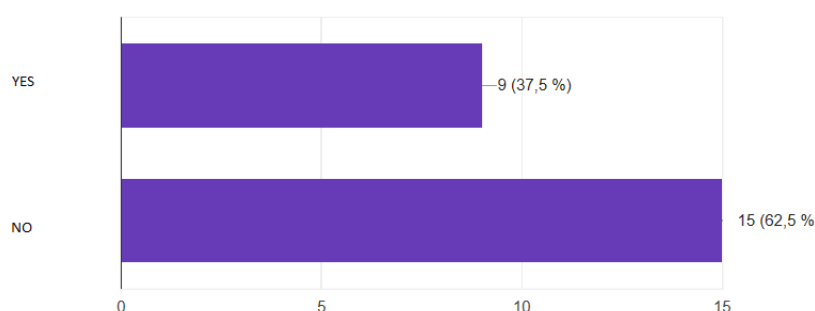


Figure 3 Implementation of the OG 4/2010 requirements

It is noticed that over 50% of ATUs have not yet begun to implement, and the main reason is the financial component, the lack of funds, the budget non-allocation. Nevertheless, 34.8% of the respondents stated that at ATUs level there are data sets related to them, with modest coverage, as shown in Figure 4.

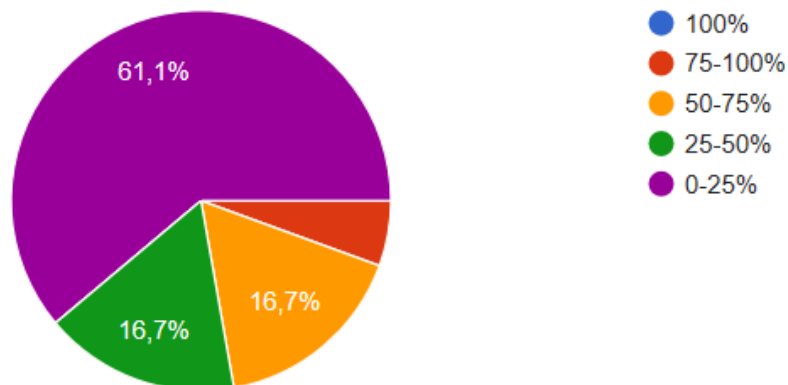


Figure 4 Degree of coverage of existing spatial data in ATU

Regarding the existence of dedicated IT tools, with the same motivation of the lack of necessary funds, a major lack of software can be noted. Even so, in the absence of software, with delays, including regarding the planning of the implementation of GO 4/2010, at ATU level there still is the intent to develop a GIS, at 52.6% of the respondents.

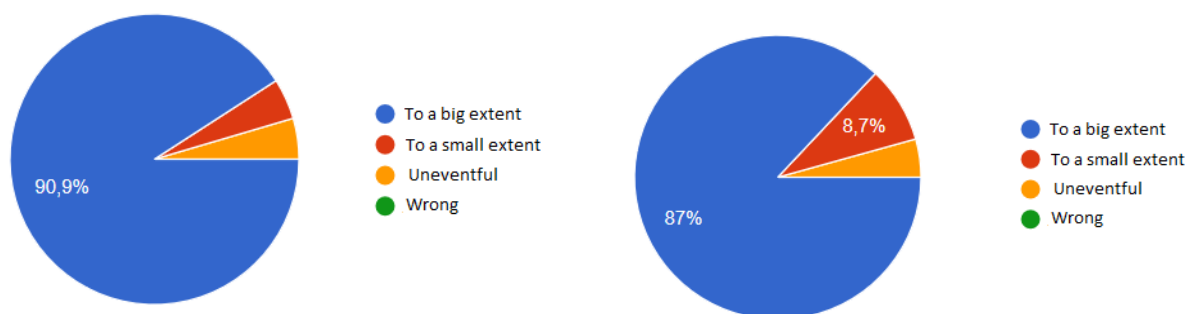
It is worth mentioning the fact that from 15 responses we received to the question "Have you started the implementation of a GIS? If so, at what level do you find yourselves?" 6.7% find themselves in the phase of up to 50% GIS implementation.

Undoubtedly, these elements clearly show the reduced capacity of ATUs to digitize spatial data and the remote perspective of implementing a GIS.

## 2.2. Availability and interest in shared use of a GIS

After collecting the information, using the created questionnaire, we concluded that there is a very high openness at the ATU level regarding the sharing of a GIS.

Figure 5, a shows the level of interest and one can see that 95% of the respondents are in favor of sharing of GIS.



a – interest in using of a shared GIS

b – utility in development using a shared GIS

Figure 5 Interest at ATU leve for a shared GIS

Figure 5, b shows that the interest is justified because of utility considerations, for the development of ATU.

Starting from the set of benefits identified by the respondent, such as the access to more and of a better quality information, simplification of data exchange between institutions, increasing the speed of solving many of the current problems, it is noted that 100% the respondents declare that a shared tool is a useful element in public administration activity, as can be seen in Figure 6, which shows the analysis of the answers to the question "Do you think that integrating a GIS with other systems (zonal or local such as of ISU, of CNADR, etc.) by exchanging information or by issuing notifications would be a useful element in your activity?" Regarding the manager and the coordinator of such a system, most of them appreciate as appropriate the location of it at the County Council or the ISU County.

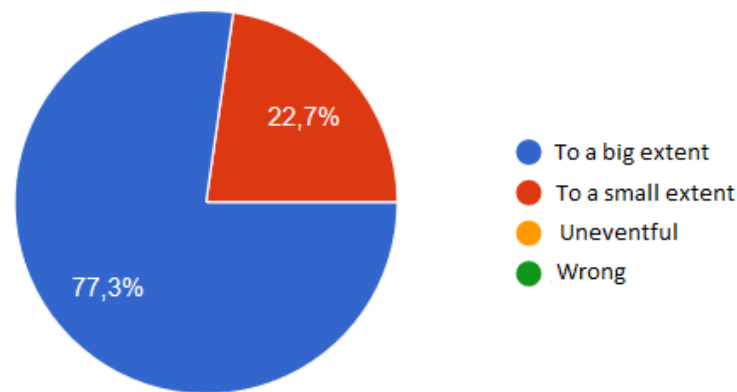


Figure 6 The utility in the activity of ATU through the integration of GIS with other systems such as ISU, CNADR

### 3. Possibilities of applying a sharing economy in a county.

Starting from the existing elements, meaning the stated need, the interest, the available resources and the existing circumstances, we identified two possibilities to be applied to achieve the goal namely the existence of a GIS that can be shared:

- The development of a GIS for the entire county, by the County Council, as we shown in the paper work "GIS, integrated solution, for efficient administration of Hunedoara County" (Jornea), with the right of the system to be used by all ATUs through a system of credits in which the unit of measure to be the money. Each ATU creates for itself a right of use, by contributing to the data of the system, contribution that is converted in money and then when use it, to consume as much as it accumulated. The proposition is to use the money as unit of measure, because this way the system would be an open one for the use for other categories of users, who, even if they could not contribute, could use it by paying with money. For ease of the system of use, the owner, being a state entity with coordination role, can generate a group of ATU in LAGs (groups with local actions) or other forms that allow the coagulation of all ATUs in several such entities and who might be users with a higher efficiency potential in using a GIS of such a scale. Currently, according to public information, in Hunedoara County, there is no such coagulation, even if many of the ATUs are part of the LAGs (List).
- The development of a GIS, for a powerful ATU or for an organized group of ATUs or even for the entire county, by a private player, in public-private partnership that to operate on the sharing economy principles, customized to ensure its sustainability and its development over time. When mentioning customization, we refer to the fact that if start is a powerful ATU, we must have into view the opportunity to expand it on neighbouring territories, the horizontal and vertical development and sustainability, and if it is about the whole county, then, we talk about vertical sustainability and development. The legal framework for public-private partnerships, described in GO 39/2018, makes it possible to clarify the responsibilities and obligations of the parties in all respects, without departing from the national security aspects.

José Manuel Barroso, in 2016, when he received the title Doctor Honoris Causa at West University of Timisoara, said, among other things, starting from the subject of Europe and of the European Union and mentioning that a student had said that when the pair EU – crisis was searched on the Internet, there was over one million results, that problem solving should not receive a punctual, short-term solution, but a long-term solution. His Excellency has shown that problems, seen in their solving as challenges, ensure progress (Agerpress). This approach is like our preoccupations in all the solutions proposed in the completed studies.

### Conclusions

Starting from this particular case, of developing, implementing and maintaining a GIS, relying on the analysis of the needs of the communities and on the local, regional and national development directions, we can replicate the principle, we can develop the idea and this way we can build a platform or many of them to allow the sharing of resources of the local communities, whether that we talk about machines, territories, or even that we speak about people with useful skills in current or periodic activity.

Platform management responsibilities can, and must, be assigned to responsible entities that to ensure full transparency in what it is shared. This way we look at the attempts to develop local communities, management in public administration and the perspective of the consistency of progress, in the conditions in which the prosperity of the citizen is a central issue. We consider that any opportunity capable of increasing the quality of management in the administration, for the benefit of the citizen, is to be considered and used. We consider that our argument in favor of sharing economy, is only one part of the tip of the iceberg, the use being, as in the case of GIS, in the statement of Jack Dangermond from ESRI, limited only by the imagination of the user.

## References

- Andreotti, A., et al., *European Perspectives on Participation in the Sharing Economy* (October 2, 2017). Available at SSRN: <https://ssrn.com/abstract=3046550> or <http://dx.doi.org/10.2139/ssrn.3046550>
- Chakravarthi Narasimhan, et al., *Sharing Economy: Review of Current Research and Future Directions, Customer Needs and Solutions*, March 2018, Volume 5, Issue 1–2, pp 93–106, ISSN 2196-291X, Cust. Need. and Solut. DOI 10.1007/s40547-017-0079-6
- Codagnone C., Martens B., *Scoping the Sharing Economy: Origins, Definitions, Impact and Regulatory Issues*, EU Science HUB, (2016), <https://ec.europa.eu/jrc/en/publication/eur-scientific-and-technical-research-reports/scoping-sharing-economy-origins-definitions-impact-and-regulatory-issues>
- Horton, John J., Zeckhauser, Richard J., *Owning, Using and Renting: Some Simple Economics of the “Sharing Economy”*, NBER Working Paper No. 22029, Issued in February 2016, (DOI): 10.3386/w22029
- Jornea, E., Lupu-Dima, L., Edelhauser, E., *GIS, Integrated Solution, for Efficient Administration of Hunedoara County*, Conference: 8th International Conference on Manufacturing Science and Education (MSE) - Trends in New Industrial Revolution Location: Sibiu, ROMANIA Date: JUN 07-09, 2017  
Sponsor(s): Lucian Blaga Univ Sibiu, Fac Engn, Ind Engn & Management Dept; Lucian Blaga Univ Sibiu, Fac Engn, Ind Machines & Equipment Dept 8TH INTERNATIONAL CONFERENCE ON MANUFACTURING SCIENCE AND EDUCATION (MSE 2017) - TRENDS IN NEW INDUSTRIAL REVOLUTION Book Series: MATEC Web of Conferences Volume: 121 Published: 2017, Book Series: MATEC Web of Conferences, DOI: 10.1051/mateconf/201712106004, Publisher E D P SCIENCES, 17 AVE DU HOGGAR PARC D ACTIVITES COUTABOEUF BP 112, F-91944 CEDEX A, FRANCE , Accession Number: WOS:000435283800074, ISSN: 2261-236X
- Miller, Stephen R., *First Principles for Regulating the Sharing Economy* (February 2016). 53 Harvard Journal on Legislation 147 (2016). Available at SSRN: <https://ssrn.com/abstract=2568016> or <http://dx.doi.org/10.2139/ssrn.2568016>
- \*\*\*, (Future of Urban Development and Services), *Collaboration in Cities: From Sharing to ‘Sharing Economy’*, White paper - The World Economic Forum published on 20 December 2017, <https://www.weforum.org/whitepapers/collaboration-in-cities-from-sharing-to-sharing-economy>
- \*\*\*, (Lista) [http://www.madr.ro/docs/dezvoltare-rurala/Axa\\_LEADER/2014-2020/2017/Lista-Grupuri-Actiune-Locala-selectate-de-MADR-si-datele-de-contact-ale-acestora-actualizare-24.05.2017.pdf](http://www.madr.ro/docs/dezvoltare-rurala/Axa_LEADER/2014-2020/2017/Lista-Grupuri-Actiune-Locala-selectate-de-MADR-si-datele-de-contact-ale-acestora-actualizare-24.05.2017.pdf)
- \*\*\*, *Guvern, Programul de guvernare 2017 – 2020*, <http://www.cdep.ro/pdfs/oz/Program%20de%20Guvernare.pdf>
- Agerpress, José Manuel Barroso, *Doctor Honoris Causa, Universitatea de Vest Timișoara (UVT)*, <https://www.youtube.com/watch?v=KqggfQGRXw>

## Innovation Management Correlated with the Models of Development of Technological Entrepreneurship

Amalia Furdui<sup>a\*</sup>, Eduard Edelhauser<sup>a</sup>, Elena-Izabela Popa<sup>a</sup>

<sup>a</sup>University of Petrosani, University Street, No.20, Petrosani, 332006, Hunedoara

---

### Abstract

The paper presents the main features of the methods for the development of technological entrepreneurship, which could be correlate with the innovation management. The European Union promotes entrepreneurship as a key factor for competitiveness and underlines the importance of developing an entrepreneurial culture on a European scale. An important feature of the contemporary age is the development of the scientific and economic disciplines of the interface, an essential characteristic of the knowledge society, which attempts to respond to the growing complexity of economic and social realities, which requires interactive and innovative approaches.

**Keywords:** entrepreneurial; innovative process; competitiveness; models

---

### 1. Theoretical Framework

In the last decades after the manifestation of the economic crisis, the importance of the Entrepreneurship for the affirmation of growth and economic development at the global level represented a topic, which has captured the interest of researchers and practicing aspects of multidimensional relationships, because of the phenomenon, with implications in micro- and macro-economic.

The policy of the European Union (EU) in the field of entrepreneurship highlights the constant need to create the most appropriate micro and macro-sized to support the development of small and medium-sized enterprises and entrepreneurship (Román, 2013).

The studies in order to achieve innovation reflect the developments in the way of achieving innovation, the linear approach of the activities of research, development and innovation - with the sequence of activities carried out successively in the framework of the specialized structures of the company, at the complex interactive models, which requires a high level of collaboration, both within the organization and with other organizations (Tidd, 2006). The most popular theory in respect of models of innovation is assigned to Henry Chesbrough (2003), which presents new paradigms of innovation, compared with the traditional. "Open Innovation" (open) and "Closed innovation" - are assigned Chesbrough expressions of the two approaches.

Closed Innovation - defines the traditional achievement of innovation, successfully applied for a long period of time, Companies that exploit the results of research on its own have, become leaders on the market, but failed to anticipate the competition. The basic characteristic of this model is a greater degree of integration for research activities, development and innovation, both in order to generate new ideas and development

Figure 1 illustrates the innovation closed, characterized by carrying out the flow of research-development and innovation between the boundaries of the company. The process can be seen in the form of a funnel (innovation funnel), with a large number of ideas and concepts at the entrance, from which they are sorted and developed those which correspond most closely to the requirements.

---

\* Corresponding author. Tel.: 0742040807  
E-mail address: Iulia\_amalia@yahoo.com



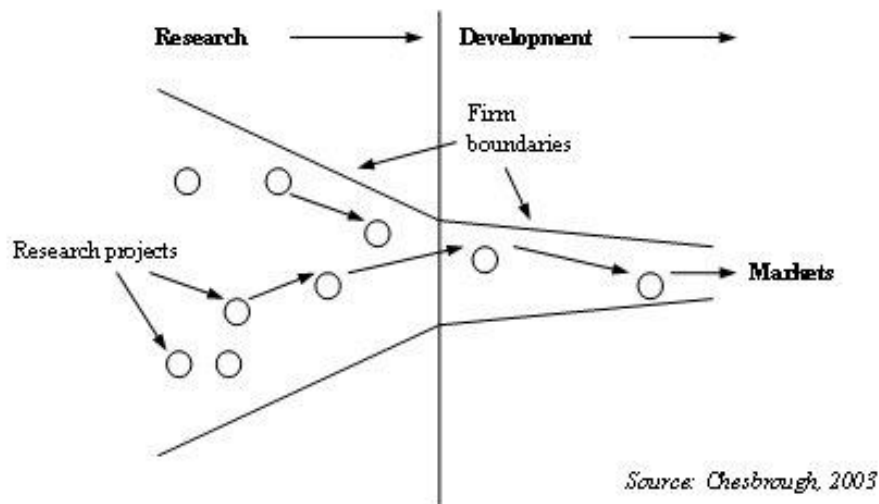


Fig. 1. Innovation closed

This model of the innovation is characteristic of the 20th century, has been deemed to be tacitly renewed, as the best route to bring new products to the market. Successful companies have played according to certain rules, the default settings. They have invested in research and development more than competitors. Those investments secured their leading position on the market with important profits and economic results, which enabled them to protect their creations by maintaining a real monopoly on their commercial exploitation.

Open innovation - defines a new philosophy of making the cycle research-development and innovation, which involves combining various sources of internal and external ideas, with the pathway of recouping on the market of new products and new technologies. This is the "Use of the inputs and outputs of knowledge in order to accelerate innovation, respectively, the extension of the markets for external use of innovation" (Chesbrough et al., 2006, p.1).

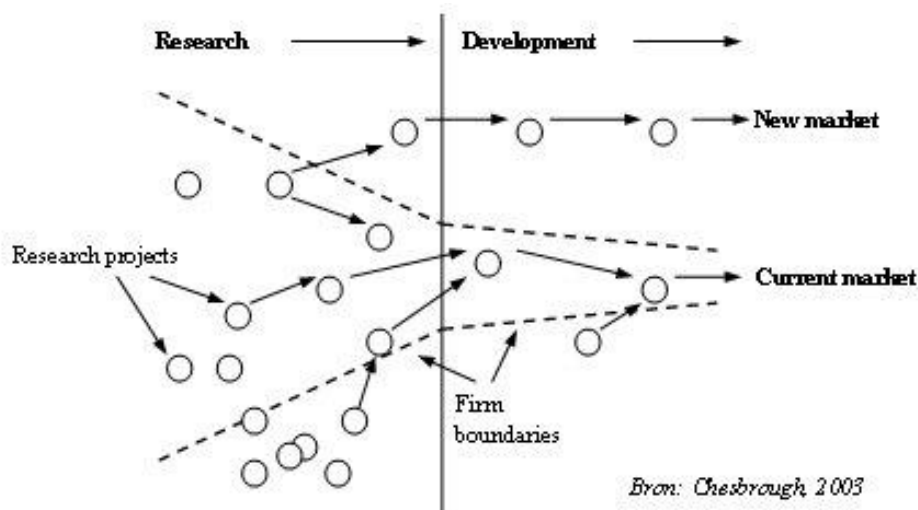


Fig. 2. Innovation open

The figure above illustrates the Open Innovation, characterized by complex flows of the activities of research, development and innovation, which integrates both internal processes and processes that crosses the boundaries of the firm. In essence, the innovation open presupposes the development of a system based on cooperation, including the possibility that a company to adopt different solutions for innovation (use of resources and internal creation, cooperation with customers, suppliers and competitors for the creation of added value for the consumer, developing partnerships and strategic alliances with other organizations in order to achieve some common projects for research-development and innovation, etc).

Open innovation is a model adopted by an increasing number of firms. Rules governing the actions were different from a company to another, and the new philosophy of innovation explains the success for small, surprising companies, which they managed to develop new technologies becoming serious competitors without having its own research laboratories.



The transition from the traditional innovation system to the new, open extended and collaborative innovation philosophy, has multiple causes. This transformation is the result of the changes that have occurred in the business environment and in society, in the conditions of sharpening competition and accelerating technical, scientific and social progress. Among the factors that contributed to this new orientation in innovation can be remembered: increasing R & D expenditure, the effort being hard to sustain even by large companies; growing complexity of the problems faced by mankind, imposing collaboration and convergence of forces to reduce risks and speed up the completion of R & D and innovation projects.

## 2. Performance evaluation of innovation and methodology of performance evaluation

The knowledge-based society, in the context of globalization, the approach of innovation in terms of the system has exceeded the boundaries of a country. The approach as a system of innovation is made at European level (Kaiser, 2005), respectively at regional level (Cook, 2003; Bruijn & Lagendijk, 2005).

At European Union level, the initiative of "Innovation Union" (a union of Innovation) establishes an integrated approach to innovation and strategic planning, the aim being strengthened by the competitiveness of the European economy. This Guideline is summed up in the strategies of the European Communities for the beginning of the century, the Lisbon Strategy (European Commission Directorate-General for Agriculture, 2000) and "Europe 2020" (European Commission Directorate-General for Agriculture, 2010).

An essential element of systems of innovation at national and regional level is the systematic assessment of the performance of the innovation, on the basis of specific indicators. In this context, the indicators represents data which reflect the fault of third countries in the field of science and technology development. That demonstrates the strengths and weaknesses, namely the changing trends.

The observation of those indicators allows measurement of the ripening system of innovation and may help to determine trends Seidel production (a.s., 2013). The most well- known system for measuring the performance of the innovation, is the following: the system of indicators proposed by the OECD in the eighties of the last century for performance analysis at the level of the country, region or sector, published in numerous reports under the name of "Frascati manual"; In the '90s, Eurostat started the publication of the report the European Parliament on the indicators for the assessment of science and technology, synthesized in the Workshop Oslo", by which the European Commission has created a basis for the development of statistics on science and technology.

Beginning in the year 2000, in the framework of the European Union was introduced a new methodology for the evaluation of the performance of the innovation, under the name of "European Innovation Scoreboard (EIS). This indicator provides a comparative assessment of the performance of the research and innovation of the EU Member States and third countries selected, as well as the strong points and weak points of their systems for research and innovation and help countries to assess the areas in which they must focus their efforts to improve performance in the field of innovation.

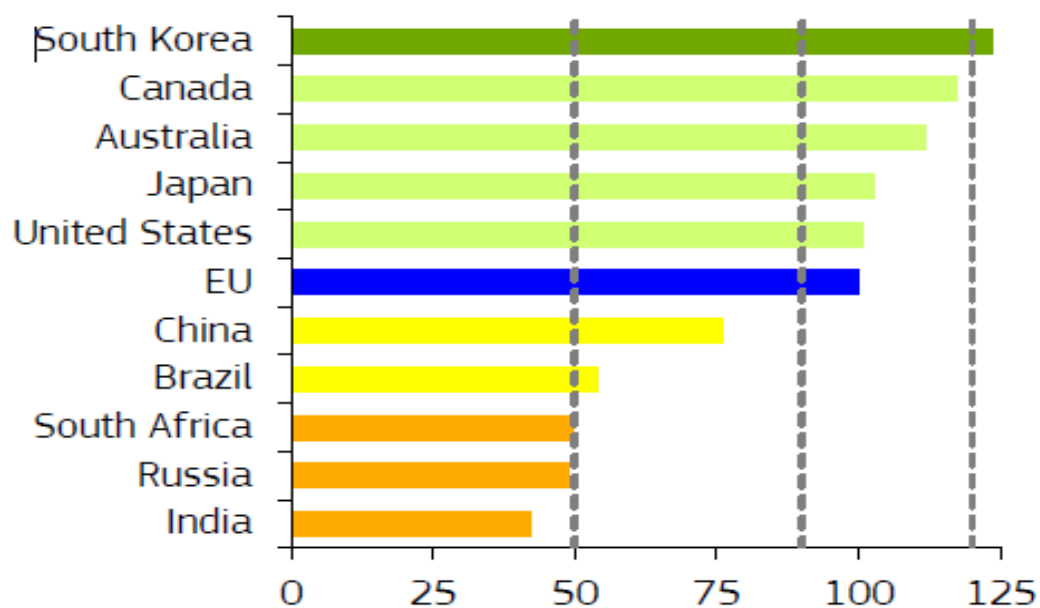


Fig. 3. Global performance /X axis (%) represents dimension composite innovation index calculated as the un weighted average of the re-scaled scores for 27 indicators within the respective dimension

At world level, the EU continues to improve its position relative to the United States, Canada and Japan. As regards South Korea, EU has fallen behind, but he expects a gradual process of alignment in the next few years. The People's Republic of China reaches up to three times the rate of increase of the performance of the innovation at EU level. The performance of the EU from Brazil, India, Russia and South Africa remains considerable. Barile shows the performance of the countries in 2017 compared with the EU in 2017. The dotted lines show the values of the thresholds of groups of performance in 2017.

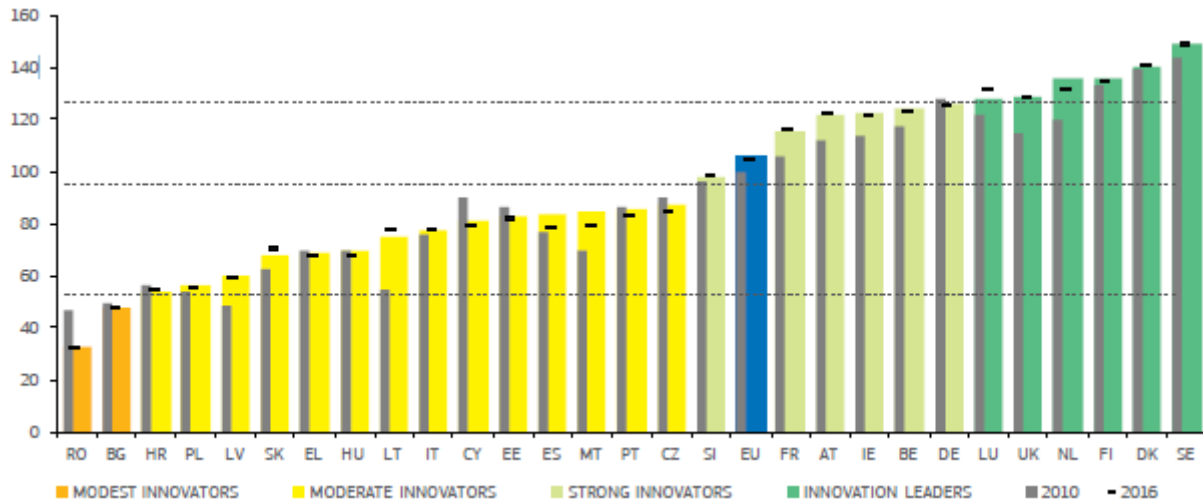


Fig. 4. Performance of EU Member States' innovation systems/ (X axis (%)) represents dimension composite innovation index calculated as calculated as the unweighted average of the re-scaled scores for 27 indicators within the respective dimension  
(Source: European Innovation Scorebord 2018)

Those 27 indicators relates three aspects: the drivers of innovation, business activity and innovation outcomes. Depending on the level of the SII (Summary Innovation Index), the Member States of the European Union fall into one of the following four categories: innovation leaders, innovation followers, moderate innovators and modest innovators.

The colored columns indicate the performance of the Europe States in 2017, using the most recent data for 27 indicators –, as compared to that of the EU in 2010. The horizontal lines show the performance in 2016, using the most recent data for 27 indicators, compared with that of the EU in 2010. Gray columns indicate the performance of the Member States in 2010 compared with the EU in 2010. For all those years same methodology of measurement has been used. The dotted lines show the values of the thresholds of the groups of performance in 2017, comparing the performance of the Member States in 2017 compared with the EU in 2017.

On the basis of average calculated performance of a composite indicator (index summary of innovation) Member States fall into four groups of different performance: Denmark, Finland, Luxembourg, the Netherlands, Sweden and the United Kingdom are leaders of innovation with the innovation performance than the EU average. Austria, Belgium, France, Germany, Ireland and Slovenia are innovators strong with superior performance or close to the EU average. The performance of Croatia, Cyprus, Czech Republic, Estonia, Hungary, Greece, Italy, Latvia, Lithuania, Malta, Poland, Portugal, Slovakia and Spain is below the EU average. Those countries are innovators and moderate. Romania and Bulgaria are modest innovators with performance with far below the EU average.

This year, the Luxembourg (formerly a strong innovative) join the group of leaders of innovation, while Germany (the leader of innovation), join the group of strong innovators. However, the differences between the overall performance of some leaders of innovation and the best innovators powerful are small.

Strengths and weaknesses of composite indicator:

- strengths (composite indicators are useful in summarizing information, composite indicators produce easy to read graphs, composite indicators reach larger public and thereby raise media)
- weaknesses (Composite indicators hide differences in underlying indicator performance, composite indicators can lead to wrong policy conclusions)

In conclusion, the annual evaluation allows the comparative analysis of the research and innovation performance of the EU Member States and the areas where they need to focus their efforts to improve performance. Romania has experienced continued economic growth and a positive evolution of most of the macroeconomic indicators in recent years, mainly due to investment and exports. However, Romania's innovation performance remains weak compared to other EU countries. In the latest EU innovation scoreboard, Romania has fallen well below the EU average for almost all indicators. The innovative profile of Romanian companies is still very low.

This is largely due to the specific economic difficulties of the transition period, where a very low level of innovation spending in enterprises has been aggravated by an insufficient level of public funding for innovation. The main economic areas with higher levels of innovation still belong to more traditional industries such as electricity and electronics, the food and beverage industry, furniture production, metallurgy, mechanical engineering, and transport and communications.

### **3. Evaluation of technological entrepreneurship at regional and global level**

Understanding the essence of innovation management also involves benchmarking with entrepreneurship, a concept that has been known for over two centuries, which has been heavily promoted in academic and business environments in recent decades as a key factor in competitiveness and economic growth.

The last years marked the emergence of a series of indicators and indicators for comparative benchmarking of entrepreneurship in different countries, offering perspectives with varying degrees of exhaustiveness on the phenomenon investigated, including:

- Entrepreneurs International – OECD (Organization for Economic Co-operation and Development) - specific database, provides annual information on entrepreneurship
- World Bank - Indicators Group - World Bank's series of World Bank indicators and databases, geographically and temporally consistent, aims at developing business and the business environment in general, as well as entrepreneurship and small business Monitor
- GEM (Global Entrepreneurship - a large-scale project coordinated by the Global Entrepreneurship Research Association, which measures national entrepreneurship both on the basis of attitudes, perceptions, activities and aspirations of individuals, and on the views of experts on environmental factors and conditions affecting the development of entrepreneurship
- REDI (Regional Entrepreneurship and Development Index) - composite index developed at the request of the European Commission by four famous research institutions, assesses the development of entrepreneurship by region in the EU member countries
- GEDI (Global Entrepreneurship and Development Index) - the composite composite index developed by the Global Entrepreneurship and Development Institute (GEDI), evaluates individual, institutional and institutional entrepreneurial attitudes, abilities and aspirations

In contrast with indicators, indicators and databases addressing entrepreneurship in a sequential way, the need for this study is required by proposing a synthetic and complex model for entrepreneurship assessment, taking into account the specific requirements of the EU countries. The features of entrepreneurship are conceived through the construction of four pillars: the "Innovation" pillar based on The Global Innovation Index (GII) (Cornell University et al and the Summary Innovation Index (SII)), the "Change" pillar (with one explanatory variable) based on the Elasticity Index FM Global Resilience Index (GRI) (FM Global), the "Competitiveness" pillar (also with one explanatory variable) developed on the basis of the Global Competitiveness Index (GCI) (WEF, 2013).

Romania's results confirm the inefficiency of entrepreneurial education. But on the other hand, the lack of national entrepreneurship is recognized in Romania, so the first steps have already been taken in this respect, by facilitating procedures for setting up a new company (attractive startup conditions compared to other EU countries or the European average) and constant investing in entrepreneurial education.

### **4. Conclusions**

Starting from the values of the EU countries, a few conclusions can be drawn, pragmatically reflected in the necessary directions for action at European level, for the assertion of competitive economies, sustainably based on supporting the entrepreneurial phenomenon. First, it is recommended to invest in the economic- as a basic condition and a prerequisite for the development of entrepreneurship. Secondly, the awareness of the decisive influence of culture on the national entrepreneurial character calls for increased attention to the economic and social factors that sustain or inhibit the maturity of the entrepreneurial mentality, and calls for a continuous correlation with entrepreneurial education and its role at national level and, third, only entrepreneurial education is not enough to add to the economic, administrative and cultural factors and its support is only an initial step taken at the beginning entrepreneurial development, which needs to be replaced by measures in the economic and administrative sphere.

Innovation is the key engine of growth in the market economy. The ability to innovate is crucial not only for the survival of individual companies but for the sustainability of the whole economy of modern society. The way innovation has evolved over time, the shift from "closed innovation" to "open innovation" being the most a popular theory about the changes that have taken place in addressing innovation.

Many countries still face major challenges in improving productivity and efficiency processes for emerging innovations.

## References

- Bruijn, P.J.M., Lagendijk, A., *Regional innovation systems in the Lisbon strategy. In: European Planning Studies*, 13(8), (2005).
- Chesbrough, H., *Open innovation: The New Imperative for Creating and Profiting from Technology*, Harvard Business School Press, (2003).
- Chesbrough, H., *Open Innovation: A New Paradigm for Understanding Industrial Innovation*, Oxford University Press, (2006).
- Cook, Ph., *Strategies for Regional Innovation Systems: Learning Transfer and Applications*, United Nations Industrial Development Organization, Vienna, (2003).
- Isaksen, S., Tidd, J., *Meeting the Innovation Challenge: Leadership for Transformation and Growth*, (2006).
- Kaiser, R., Prange, H., *Missing the Lisbon Target? Multi-Level Innovation and EU Policy Coordination*, Cambridge University Press, (2005).
- Popescu, M., *The management of the innovation*, Transilvania University of Brasov, Publishing House, (2016).
- Román, C., Congregado, E. and Millán, J.M., *Start-up incentives: Entrepreneurship policy or active labour market programme*, *Journal of Business Venturing*, 28(1), p. 151-175, (2013).
- Seidel, U., Müller, L., Meier, G., Filho, G., *A new approach for analysing national innovation systems in emerging and developing countries. In: Industry & Higher Education*, Vol. 27, No 4, p. 279–285, (2013).
- Tidd, J., *Innovation models. A model of innovation models*, Imperial College London, (2006).
- \*\*\* WEF-World Economic Forum, 2013. The Global Competitiveness Report 2015-2016. ([http://www3.weforum.org/docs/gcr/20152016/Global\\_Competitiveness\\_Report\\_2015-2016.pdf](http://www3.weforum.org/docs/gcr/20152016/Global_Competitiveness_Report_2015-2016.pdf)) The national strategy for research, development and innovation, 2014-2020, the Ministry of Education, (2014).
- \*\*\*, Europe 2020: Commission proposes new economic strategy, European Commission, (2010), European Innovation Scoreboard 2018- [https://ec.europa.eu/growth/industry/innovation/facts-figures/scoreboards\\_en](https://ec.europa.eu/growth/industry/innovation/facts-figures/scoreboards_en), Private Sector Interaction in the Decision Making Processes of Public Research Policies Country Profile: Romania.

## Group Development Process in Management of Work Teams

Roland Iosif Moraru<sup>a</sup>, Tomasz Dub<sup>b</sup>, Mariusz Sroka<sup>c\*</sup>

<sup>a</sup>University of Petrosani, Universitatii 20, Petrosani 332006, Romania

<sup>b</sup>Training Partners Ltd., Jasna 31B, Gliwice 44-122, Poland

<sup>c</sup>Czestochowa University of Technology, J.H.Dabrowskiego 69, Czestochowa 42-201, Poland

---

### Abstract

The study defines the concept of group development process as a set of phenomena occurring in groups and work teams as well as in all formal and informal social units. The various stages of team development are presented and characterized, including: dependence, differentiation, crisis of responsibility, attack on the leader, creativity and real capabilities of the team. The attention is paid to the inevitability of the existing group process mechanisms occurring always in a specific order. These mechanisms may have varying intensity and duration, and are dependent on the situation, group composition, behavior and decisions of team leader. For individual phases of the group development process, negative and positive actions of managers managing work teams were selected. The practical part of this study presents the results of research conducted among the managers of every managing level, referring to the knowledge, awareness and use of group development process phenomena in achieving the objectives of the managed employee group. The study finishes with the conclusions and proposals for future research in the field of discussed issues.

**Keywords:** group development process; management; work teams; quality of management.

---

### 1. Introduction

The basis for effective management of employee teams is knowledge and skillful use of processes taking place in all formal and informal groups. The group development process begins when a group of people meet to achieve a specific goal. This goal may be closely related to the company's operations or be an act in the sphere of privacy. It is important that the team created is effective and focused on achieving the goals set. Understanding the phenomena occurring during the formation and operation of teams allows them to consciously manage and react appropriately to emerging crises.

The group process was first described by Bruce Tuckman in 1965 and, according to the author, included four following phases: testing and dependence, intergroup conflict, cohesion, and functional roles. Further research led to the addition of supplementary phases in subsequent years. Currently, it is assumed that the group process has six phases, which include: dependence, differentiation, crisis of responsibility, creativity and real capabilities of the team (Andrew, 2012; Bonebright, 2010). The individual stages of the group process are described in the next chapter.

If we want to provide a synthetic definition of the group process, we can say that "the group development process is the stages through which a group of people goes through in order to form a team". It should be noted that the duration of the group development process is undefined and it can not be concluded that it has ended and is closed. The group process runs in a loop, which means that whenever there is a change in the team, the team formation process starts again. It should be remembered that in every repeated cycle the goal is to improve and we can achieve it only by controlling the process (Davis, 2016; Lee et al., 2016; Pachura and Hairul, 2018; Scherrer et al., 2016).

Properly used mechanisms of the group development process may be an internal determinant of improving the quality of management in the organization. This applies especially to intangible areas, i.e. improving the quality of team management and the best use of human resources available to the organization. As a result, there is an increase in the level of competitiveness of the organization and improvement of the quality of the offered products.

The aim of this study is to get to know the answer to the question, what percentage of managers know the concept of group development process and what percentage has been trained in this area. In addition, they wanted to know the opinion of the respondents on the usefulness of group processes training for more effective management of employee

---

\* Corresponding author. Tel.: +48 34 325 03 78; fax: +48 34 361 38 76.

E-mail address: mariusz.sroka@wz.pcz.pl.

teams. The utilitarian purpose of the study was to distinguish characteristic phenomena occurring while managing employee teams and to diagnose whether respondents apply appropriate solutions to the specific problems occurring in the various phases of group development.

## **2. Phases of group development**

Individual stages of the group's development (the team of employees), which include: dependence, differentiation, crisis of responsibility, attack on the leader, creativity, real possibilities of the group occur after each other and the order mentioned here. They can have different intensity and duration, depending on the group's composition, group's goal, decisions made by the leader and many other factors. The group may under certain circumstances go back to the earlier phase or stop in development on one phase. In some specific situations, keeping the group longer in certain phases may be beneficial for the entire organization (Andrew, 2012; Bonebright, 2010; Pinto et al., 2018).

### *2.1. The dependence phase*

This phase refers to the formation of a team or the emergence of a new leader. It is characterized by fairly high passivity in that members of the group listen to commands, do not contradict themselves, do not criticize and do not reveal themselves with their thoughts. At the basis of such behavior lies the fear of negative assessment and loss of acceptance of other group members and the leader. Improper conduct of the leader in this phase is the application of sanctions and penalties for lack of commitment, instruction, threatening, ridiculing and causing a sense of guilt among the team members. Positive actions are: clarifying the team's requirements, standards, values, motives and goals and attempting to integrate the team by ordering tasks for joint implementation. Good practices in this phase are also understanding the team's behavior and activating to independent initiatives (Andrew, 2012; Bonebright, 2010).

### *2.2. The differentiation phase*

The differentiation phase is characterized above all by the fact that the members of the group perceive and emphasize the differences between themselves, have a need to stand out, make themselves known, are willing to participate in discussions and express their views (Bratu and Cioca, 2018). In this phase, violent and emotional conflicts may arise. This is due to the fact that the members of the group begin to compete with each other for the team's reasons and for the inclusion of specific group roles shaping the group's structure.

The wrong actions taken by the group leader in this phase are the attempts to silence the team, applying sanctions and penalties for chaos and lack of discipline and expressing negative emotions. Positive actions of the team leader at this stage include: adjusting to the energy and climate of the group, modeling constructive feedback, determining acceptable boundaries for individual behaviors, and insightful knowledge of the group structure for optimal use of the set tasks in front of the managed team.

### *2.3. The crisis phase of responsibility*

In the phases of dependence and differentiation, the members of the employee team have a very positive opinion about the company and the way it operates. The next phase - the crisis of responsibility - is characterized by a gradual perception of shortcomings and negative aspects of the functioning of the organization. This manifest itself in complaining, criticizing all decisions and ideas, discouragement, criticizing working conditions. Team members usurp the right to greater independence, independence and trust with the lack of willingness to take on an adequate responsibility. In the long-term, this phase is harmful, it limits initiative and enthusiasm and demotivates the team.

Negative actions that can be taken by the leader in this phase include: an attempt to translate and convince that everything is fine, applying sanctions and punishments to critics and intimidating the team. The appropriate actions are: assigning independent tasks, inducing responsibility for the proposed changes and declaring support provided that subordinates are involved in the search for and implementation of solutions (Ihil and Hellya, 2017).

### *2.4. The phase of attack on the leader*

The next phase, the attack on the leader, is an unconscious rebellion of the team, which is an emotional reaction to the frustration resulting from the belief that reality will not change for the better without the group's participation in bearing the responsibility and consequences of the choices made. The team's reactions in the attack on the leader include, among others: excessive and unjust criticism, accusations, claims and the pursuit of confrontation.

The wrong actions of the leader in this phase include: translation, polemic, dementing of charges, counterattack, dismissal of individual team members and, as a last resort, resignation from running a group. The right actions a leader can take at this stage are to wait an attack and talk about what the team should do in this situation. Then emotions fall and the attack phase on the leader goes by itself. It turns out then that the team is aware of the responsibility for the actions taken and does not avoid it (Hammar Chiriac, 2008).

### 2.5. Creative phase

A positive end to the attack on the leader phase evolves into the creative phase. This phase is characterized by the appearance among the team members of a sense of belonging to an extraordinary, unique group capable of performing very difficult and responsible tasks.

The basic mistake a leader may make in this phase is the conviction that such a state will be permanent. In addition, the leader should not present the team with a vision of above-average success in the future and raise the requirements in relation to the group. Positive action of the leader in this phase is the involvement of the team in solving particularly difficult and ambitious tasks (Farh and Chen, 2018).

### 2.6. The phase of the group's real possibilities

This phase is characterized by high responsibility and independence of team members. The group itself organizes, supports, distributes tasks and solves problems. It can be said that he understands fully his real possibilities, being aware of the advantages and disadvantages of the organization in which he works and the possibilities and limitations of his and the leader.

Improper actions of the leader in this phase are putting pressure on achieving unrealistic goals and constant and detailed control of the team's work. Positive activities include allowing the group to self-organize tasks and partnering with and appreciating achievements (Gren et al., 2017; Knight et al., 2016; Mason et al., 2016).

## 3. Research methodology

Questionnaire surveys were carried out from July 23 to August 14, 2018. Respondents were managers managing employee teams in production and sale departments in Poland. The condition for participation in the study was at least five years of experience in managing and managing employee teams. Taking part in the study was voluntary and preceded by the verbal consent of the respondent. 65 questionnaires were conducted, of which 62 questionnaires were classified after checking the correctness of the fulfillment, consistency and logic of the answers provided for further analysis. The questionnaire contained 12 questions. All questions in the questionnaire were closed questions. Five questions were one-choice and the other multiple-choice.

The aim of the conducted research was:

- Determining whether respondents know the concept of a group process;
- Obtaining knowledge whether the examined group had a training in the use of mechanisms taking place in employee teams;
- Separation of characteristic phenomena occurring while managing employee teams;
- Diagnosing whether respondents use the right solutions to specific problems occurring in individual stages of group development;
- Getting to know the opinions of the respondents on the usefulness of group processes training for more effective management of employee teams;

The test results are presented graphically or compiled in tables and analyzed in the chapter below.

## 4. Presentation and discussion of research results

The first question asked about the concept of the group development process. In the surveyed group of managers, 84% know this concept, while 16% indicated the ignorance of this concept. The results of the survey for this survey question are presented in Figure 1(a).

The second question was the question about training in the use of mechanisms taking place in employee teams. 55% of managers indicate that they had such training, while 45% said they did not. The results of the survey for this survey question are presented in Figure 1(b).

The purpose of the next question was to distinguish characteristic phenomena and attitudes while managing employee teams with which managers usually meet. The most responses were answered by: competition in the team, crisis in the team, as well as independence and responsibility. The least indications were: passivity of the team, creativity and irrational criticism, accusations and complaints. The test results for this part of the survey are summarized in Table 1.

The next question was to identify the right actions in the group development process undertaken by managers in the dependency phase. The respondents (94% and 84% respectively) correctly pointed out the appropriate actions, i.e. to explain to the team the requirements, standards and objectives, and to try to integrate the team by ordering tasks for joint implementation. Erroneous answers were given by 16% and 6%, respectively, indicating sanctions and penalties for not engaging and causing a sense of guilt among the team members. The test results for this part of the survey are summarized in Table 2.

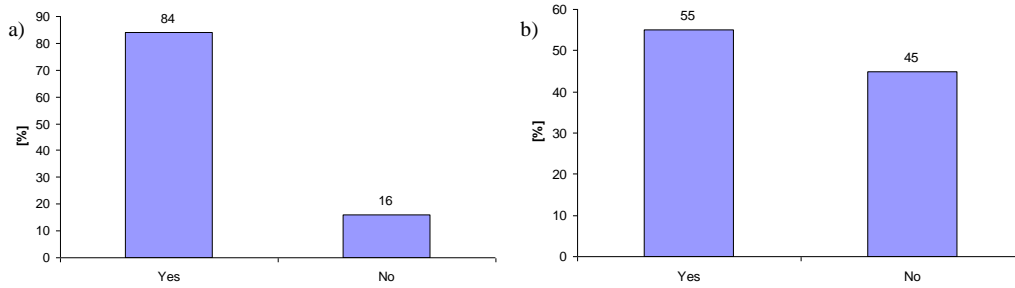


Fig. 1. (a) Knowledge of the concept of group development process; (b) Training in the field of mechanisms taking place in employee teams

Table 1. The phenomena observed during managing employee teams

Answers	Indication [%]
The total dependence of the team on the leader - the passivity of the team	42
Team rivalry - separating particular individuals	65
Crisis in the team - lack of independence and willingness to take responsibility by team members	61
Rebellion - unreasonable criticism of the leader, accusations and grievances	29
Enthusiasm - a sense of "power" in the team	35
Real possibilities of the team - getting to know their own skills, independence, responsibility	55

Table 2. Actions undertaken in the dependency phase

Answers	Indication [%]
Sanctions and penalties for lack of commitment	16
Explaining to the team the requirements, standards and objectives of the project	94
Developing a sense of guilt among team members	6
An attempt to integrate the team - ordering tasks for joint implementation	84

The next question was to identify the right actions in the group process undertaken by managers in the differentiation phase. After 84% of the respondents, as appropriate actions indicated the determination of acceptable boundaries for individual activities and learning the structure of the group and the optimal use of its possibilities. A relatively high percentage (26%) incorrectly indicated "silencing" individuality in the group and 6% for the application of penalties and showing reluctance. The test results for this part of the survey are summarized in Table 3.

Table 3. Measures to be taken in the differentiation phase

Answers	Indication [%]
"Silencing" individuality in a group	26
Setting of acceptable limits for individual activities	84
Applying penalties and showing reluctance	6
Knowledge of the group structure and optimal use of its capabilities	84

The next question was to identify the right actions in the group process undertaken by managers during the crisis of responsibility. Correct responses were given by the respondents indicating that the team was encouraged to take responsibility for what the team wants to change (61%) and to declare support provided that the team is involved (98%). Wrong answers were indicated: convincing the team that it was not bad (39%) and sanctions and penalties for critics (3%). The test results for this part of the survey are summarized in Table 4.

The next question was to identify the right actions in the group development process undertaken by managers in the phase of attack on the leader. Correct respondents indicated a conversation with the group (100%) and waiting out the attack (71%). Incorrect answers were given by 6% of managers, pointing to the dismissal of individual team members and the dementing of charges and counterattacks (23%). The test results for this part of the survey are summarized in Table 5.



Table 4. Actions undertaken in the crisis of responsibility stage

Answers	Indication [%]
Convincing the team that it is not bad	39
Inducing the team to take responsibility for what the team wants to change	1
Sanctions and penalties for critics	3
Declaring support - provided the team is committed to finding solutions	98

Table 5. Actions taken in the phase of attack for the leader

Answers	Indication [%]
Releasing from work individual team members	6
Waiting out the attack	71
Dementing of charges and counterattacks	23
Talking with a group - what the team is going to do in this situation	100

The next question was to identify the right actions in the group development process undertaken by managers in the creativity phase. 71% of respondents gave correct answers indicating the involvement of the team in solving particularly difficult problems and 84% indicating the use of the group's enthusiasm for new, ambitious tasks. 23% of incorrect answers were given with an indication of raising the requirements in relation to the team and presenting a vision of the team's above-average success in the future. The test results for this part of the survey are summarized in Table 6.

Table 6. Actions undertaken in the creativity phase

Answers	Indication [%]
Raising requirements in relation to the team	23
Engaging the team in solving particularly difficult problems	71
Presenting the vision of the team's above-average success in the future	23
Using the enthusiasm of the group for new, ambitious tasks	84

The next question was to identify the right actions in the group development process undertaken by managers in the phase of the group's real possibilities. The right answers were given by 100% of the respondents indicating partnership treatment and appreciation of achievements, and 55% indicating the group's permission for self-organization of tasks. Erroneous answers were given by 35% of managers pointing to constant and detailed control and pressure to achieve unrealistic goals (10%). The test results for this part of the survey are summarized in Table 7.

Table 7. Actions taken in the group's real possibilities

Answers	Indication [%]
Constant and detailed control of the team	35
Allowing the group to self-organize tasks	55
Pressure to achieve high and unrealistic goals	10
Partner treatment and appreciation of achievements	100

The last question was aimed at getting to know the respondents' opinions on the usefulness of group development processes trainings for effective management of employee teams. None of the respondents indicated that such training is useless or of little use. The subject training was indicated by 19% of respondents as being of moderately usefulness. On the other hand, 39% and 42% of respondents respectively indicated enough useful and very useful. The results of the survey for this survey question are presented in Figure 2.

#### 4. Conclusions

The vast majority of managers participating in the study know the concept of group development process, and although only 55% declare that they have completed training in the use of mechanisms in employee teams, they are able to see the group process in practice and react correctly. The surveyed group of managers in most cases is able to properly identify the characteristic phenomena occurring in the group process. Most of them can also correctly indicate the right actions to solve problems occurring in each phase of the group process. Only a small percentage of respondents are inclined to use incorrect methods of solving problems in individual phases of the group development process. This is the result of the acquired knowledge and among people who have not completed the training it is associated with the experience acquired in practice. However, surveys have shown that a significant number of

managers are not aware that constant and detailed team control does not go hand in hand with partner-like treatment and self-organization of tasks by the team. This shows that training in this area should be deepened or repeated, paying particular attention to this aspect.

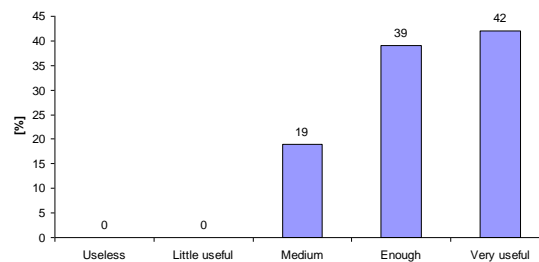


Fig. 2. Usefulness of group processes training for effective management of employee teams

The research also showed that the respondents perceive the benefits of training on group processes. All respondents indicated their suitability for more effective management of employee teams, what in the future can contribute to increasing the quality of management in the organization.

The intention of Authors is to conduct future research on group processes among team members headed by managers trained in group development processes as well as non-trained, and then comparing the results of research with the results presented in this study.

## References

- Andrew, C., The Punctuated-Tuckman: A Conceptual model for the integration of Tuckman, PEM, and systems group development theories, *Leadership & Organizational Management Journal*, Vol. 2012 Issue 1, pp. 143 - 152, (2012).
- Bonebright, D. A., 40 years of storming: a historical review of Tuckman's model of smallgroup development, *Human Resource Development International*, Vol. 13 Issue 1, pp. 111 - 120, (2010).
- Bratu, M. L., Cioca, L. I., Adaptation of managerial style to the personality of engineers in order to increase performance in the workplace, *Polish Journal of Management Studies*, Vol. 17 No. 1, pp. 67 - 77, (2018).
- Davis, Jason P., The group dynamics of interorganizational relationships, *Administrative Science Quarterly*, Vol. 61, Issue 4, pp. 621 - 661, (2016).
- Farh, C. I. C., Chen, G., Leadership and member voice in action teams, *Journal of Applied Psychology*, Vol. 103, pp. 97 - 110, (2018).
- Gren, L., Torkar, R., Feldt, R., Group development and group maturity when building agile teams: A qualitative and quantitative investigation at eight large companies, *The Journal of Systems & Software*, Vol. 124, pp. 104 - 119, (2017).
- Hammar Chiriac, E., A scheme for understanding group processes in problem-based learning, *Higher Education*, Vol. 55, Issue 5, pp. 505 - 518, (2008).
- Ihil, S. B., Hellya A., The Effectiveness of leadership management training, *Polish Journal of Management Studies*, Vol. 16, No. 2, pp. 7 - 16, (2017).
- Knight, A. P., Kennedy, D. M., McComb, S. A., Using recurrence analysis to examine group dynamics, *Group Psychology and Group Psychotherapy*, Vol. 20, No. 3, pp. 223 - 241, (2016).
- Lee, S. H., Smith, D., Sergueeva, K., What do students think about group work in business education?, *Journal of Education for Business*, Vol. 91, Issue 7, pp. 380 - 386, (2016).
- Mason, S. G., Holley, D., Wells, A., Jain, A., Wuerzer, T., Joshi, A., An experiment-based methodology to understand the dynamics of group decision making, *Social Network Modeling, Socio-Economic Planning Sciences*, Vol. 56, pp. 14 - 26, (2016).
- Pachura, A., Hairul, What matters in project team management?, *Polish Journal of Management Studies*, Vol. 17, No. 2, pp. 211 - 221, (2018).
- Pinto, A., Lourenço, P. R., Mónico, L., The knowledge management processes at different stages of group development, *Psicologia: Teoria e Pesquisa*, Vol. 33, (2018).
- Scherrer, J. L.; Olcoñ, K., Butterfield, A. K., Kebede, W., Bringing experiential educational groups to the United States: an analysis of group development in an international travel and study program, *Social Work Education*, Vol. 35, Issue 6, pp. 693 - 705, (2016).

## Analytic Dashboard, a Solution for Increasing Efficiency in Management of the Public Administration

Emilia Corina Corbu<sup>a\*</sup>, Eduard Edelhauser<sup>a</sup>, Lucian Lupu-Dima<sup>a</sup>

<sup>a</sup>University of Petroșani, University Street no.20, 332006 Petroșani, Romania

---

### Abstract

The efficiency of public sector results from public resources and is calculated with multidimensional indicators, which can evaluate the effects through consume of resource units. Analytical dashboards visualize set data for certain purpose and enables users to see what is happening and to action. Our paper identifies actual situation of these indicators for Hunedoara district from West Region, Romania in EU-statistics. Then, we present the most utilized solution for analytical dashboards. In the final part, our study presents a part of research results, realized on local administration from local district in West Region, and also the best analytical dashboard for our public administration.

Keywords: management; analytical dashboard; analytics; business intelligence

---

### 1. Introduction

In the Top of Europe, in terms of government efficiency, Romania is placed on the last place. This position is given by the value of many indicators, used in World Bank assessments. This position is given by the value of many indicators that takes into account the capacity of central and local government. Comparing Romania with other countries, it is found that the value of many public administration indicators has not changed substantially in the last 7 years.

The objective of this paper is to understand and to support the design of dashboards for creating transparency and accountability, to identify benefits and principles for designing dashboards in the public sector. Following these principles can lead in realizing the benefits and overcoming the risks.

A cycle describing the data cycle of open and private data for dashboards is presented to show how value can be created. The dashboards identifies are most often referred as a tools for the improvement of processes and performance of organizations.

### 2. The efficiency in Romanian public sector

Afonso (2006) analyzed the most used methodologies like “raw” efficiency scores, Data Envelopment Analysis (DEA), stochastic frontier, explaining inefficiency, Tobit regression and bootstrap technique and concluded with the representation of these.

In the paper Public sector efficiency, it is proposed a methodology which measures the report between the obtained results and the resources used by the public administration, calculating the indicators for the principal fields like:

1. Administration: the level of International Transparency, the level of Doing Business Report, the Global Competitiveness; the underground economy (International Monetary Fund).
2. Education: the students that graduated superior institutes or university measured by Global Competitiveness Report.
3. Medical System: Global competitiveness Report, European Healthcare Consumer Index, The Health Consumer Powerhouse.
4. Infrastructure: the quality of the infrastructure – Global Competitiveness Report.
5. Distribution: the Gross Domestic Product GDP, the Poverty Rate (World Bank Report).
6. Stability: growth rate (World Bank Report)

---

\* Emilia Corina Corbu. Tel.: +40767223677.  
E-mail address: corina.corbu@upet.ro.

7. Economic performance: GDP growth, unemployment rate, public debt level in GDP (World Economic Outlook, FMI).

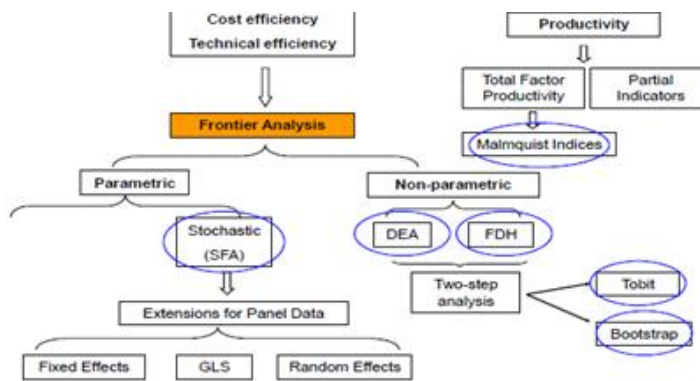


Fig. 1. Methods for measuring of efficiency of activities in public administration Source: Alfonso 2006

International Global Forum elaborate every year, The Global Report for Competitiveness, which evaluated the reforms, made for improving the efficiency in public funds. In this report is revealed that the consequences of the economic crises like, the economic growth remains low, persistently high unemployment are still felt throughout the world. Recovery was less robust than projected, while economic growth was reduced in the context of geopolitical shocks that had a negative impact on development sustainability.

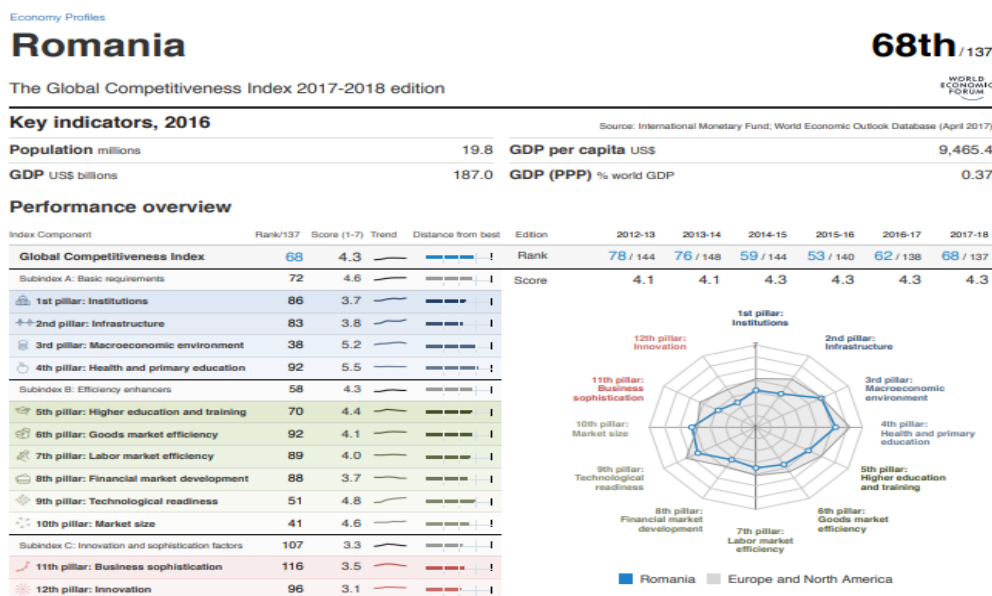


Fig. 2. The Global Competitiveness Index

Source <http://www3.weforum.org/docs/GCR2017-2018/05FullReport/TheGlobalCompetitivenessReport2017%E2%80%932018.pdf>

The Global Competitiveness Index of the above-mentioned Report places Romania on the 53rd place (2015) of 140 countries for which such assessments are made. Compared to 2014, Romania advances six places (59th place) (in the previous years, 2013, 2012, the occupied places were 76, respectively 78, showing an improvement of the overall competitiveness of the country). In 2017-2018, the Global Competitiveness Index places Romania on 68<sup>th</sup> place (2016) of 140 countries.

The Global Index is based on four Pillars: Quality of Institutions, Infrastructure, Macroeconomic Environment, Primary Education and Health. The evaluations made place Romania in the Top World (140 countries), as follows: Place 86 at Pillar 1 - Quality of institutions; Place 83 at Pillar 2 - Infrastructure, Place 38 at the Macroeconomic Environment Pillar; Place 92 at Pillar 4 - Primary Education and Health.

As regards Pillar 1 - Institutions - the global assessment shows that Romania is ranked 51<sup>st</sup> for the investor protection component, 100<sup>th</sup> place for Ethical Behaviour of Companies, 113 for Public Trust in Politicians, 116 for Favouritism in Government Decisions and on 124<sup>th</sup> place at Burden of government regulations. The last place (115<sup>out</sup> of 140) is held by Efficiency of Government Spending.

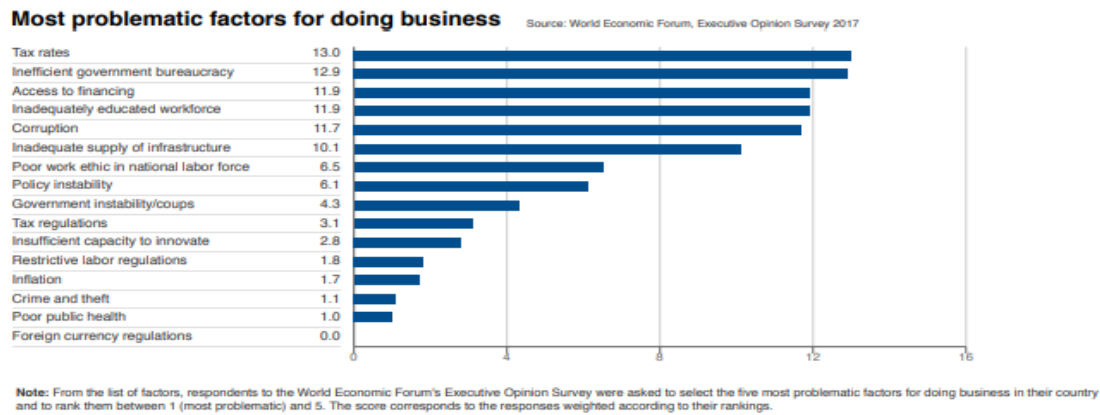


Fig. 3 Most problematic factors for doing Business in Romania

Source <http://www3.weforum.org/docs/GCR2017-2018/05FullReport/TheGlobalCompetitivenessReport2017%E2%80%932018.pdf>

Most problematic factors for doing business in Romania are Tax rates, inefficient government bureaucracy, Access to financing and inadequately educated workforce. The report states that both economic issues, as well as falling consumption and political uncertainty, lead to increased inequality in income.

So, we consider that we can contribute in two ways to correcting and improving this situation. One practical way of improving the quality of life is based on accelerating public-private collaboration through better stakeholder information through the adoption of Corporate Social Innovation by the private sector.

### 3. Dashboards in public sectors

To visualize the data in dashboards is an important area of Data science. Cleveland 2001 argues that data science consists of multidisciplinary investigations, models and methods for data, tool evaluation and theory. Data scientists need in-depth knowledge of data analytics for analyzing data as well as knowledge on the use of techniques and instruments for predictive purposes and to visualize the results. Data science is essential area for public administration. (Janssen, Matheus, & Zuiderwijk, 2015) Analytic dashboards can collect a lot of data in various areas like geographical, traffic, social security, energy etc.

Brown, Fishenden, Thompson, & Venters, 2017 concluded that can be created platforms to share data. Dashboards can be used to release information for governmental decision-makers, but also for the public to scrutinize government actions, to engage in the decision-making processes and to improve decision-making. Dashboards should help to facilitate transparency, governance, trustworthiness and enable citizens' to participate in decision-making in smart cities (Allio, 2012).

In the last years, dashboards for the public sector have gained more attention. In 2009, for example the US federal government developed dashboards with federal stimulus funding aiming and accountability of national economic recovery policy (Ganapi, 2011). Another example is the Dutch government which uses dashboards to enable the monitoring of large IT-projects by the public ([www.rjksictdashboard.nl](http://www.rjksictdashboard.nl)).

In Rio de Janeiro, Brazil, The Smart City dashboards were created to solve problems related to public transportation and traffic. For this, were created an infrastructure, a dashboard, a data portal, related databases and APIs for real-time use ([www.data.rio](http://www.data.rio)).

The dashboards created by the group Pensa have the objective of putting key organizational elements into a consolidated format using several visualization tools, gauges, graphs, charts, and pictograms ([www.pensa.rio](http://www.pensa.rio)).

### 4. Analytic dashboards. Benefits and data cycle

#### 4.1. The benefits of dashboards

The dashboards are becoming an important means of communicating and interacting with the public to create transparency and to achieve accountability. The benefits of the dashboards are classified in strategic benefits and operational benefits. The dashboards permit flexibility to create various types of overviews at glance. Also, the same flexibility allows to overview and can be used to drill into detail for any event. During the monitoring a certain process, it is possible to zoom in on a certain point of interest.

Creating views at a glance with dashboards, it means that this provide transparency. Also, enabling the creation of customized views, provide information to people at the time and place they really need it. Anomalies and patterns in data can be used to detect corruption by showing them in dashboards combined with data analytics.

The information presented in dashboards concerns the trends or issues in the city, county or region. Like operational benefits are: better and faster decision and policy-making, mobilize external knowledge, improving the effectiveness

and efficiency of operations, disclose relevant information to people, and enable participation, public participation in service improvement.

#### 4.2. Data cycle for dashboards

The main phases often followed by data scientists are data capturing, data storage, data searching, data sharing, data analysis, and data visualization (Bizer, Boncz, Brodie, & Erling, 2012). In our case, our analytical dashboard should include five different phases Data collection, Data processing, Data analysing, Data visualization, and Data. The step 'data usage' is introduced, as a value can only be created from data when it is actually used (Janssen, Estevez, & Janowski, 2014). Figure 4 shows the main information flows in the cycle. One flow is used for creating a dashboard for internal use by the government to support policy-making, whereas the other dashboards are aimed at creating transparency and accountability for the public.



Fig.4. The phases of a data cycle for analytical dashboard

A first flow included in Data Collection comes from sensors, forms by the government or generated by citizens. In Data Processing, is made a division between the Database with Public Private Data (PPD) and the Database with Public Open Data (POD). PPD cannot be shared with external parties, due legal reasons such as privacy of personal data (names, nicknames, geographical positions etc.) and confidentiality of strategic governmental data (strategic plans anti-terrorism, emergency plans, etc.).

For these reasons, a normalization and standardization is conducted on the PPD to create the POD. The two databases POD and PPD enable the creation of two different flows with different objectives. While the PPD helps government to create internal strategies for public policy, the POD can be freely used by individuals and enterprises by accessing the Open Data Portal.

The governmental flow of information public flow of information go Data Analysis. Data Analytics Processes either manually performed by data scientists or automated. The statistical analysis and geographical analysis enable Data Visualization. This stage combines results from statistical and geographical analysis into a dashboard to present for internal and external audiences. The cycles in Fig. 4 suggest that dashboards need to be continuously updated. One cycle opens data for citizens, which should result in higher levels of transparency. For citizens, various views and visualizations can be created. Due to privacy issues and for other reasons not all data might be indiscriminately shared. The second cycle opens data for a limited group of policy-makers.

## 5. IT Trends in Territorial Administrative Units of Hunedoara County

### 5.1. Research methodology and results

We achieved the results in the virtue of the questionnaires. In order to analyze the statistical connections, we used correlation analysis for the intensity of the connections between the variables and regression analysis to estimate the value of a dependent variable (effect) taking into account the values of other independent variables (causes). One part of our research was to carry out a multiple regression analysis in order to identify the effect that implementation of IT tools in Territorial Administrative Units (TAU) of Hunedoara County, has over the population. (Edelhauser, 2014).

Another part of our research was to identify the stage of IT trends in TAUs of Hunedoara County and if there are conditions for implementing an analytical dashboard like a solution for increasing efficiency in public administration.

The instrument used for collecting data is a quantitative questionnaire. We used the questionnaire as a technique for investigating the territorial administrative units in Hunedoara County regarding the IT level. The questionnaire used was focused on the level of IT using 25 questions.

The study set sights on over 11 territorial administrative units from Hunedoara County, and data were collected in 2018 year. The survey led us to identify, based on the processing of the data gathered through the questionnaires and on the statistical data existing at national and county level, some trends in IT, trends that led us to a set of measures that we will propose to the decision-makers at county. (Edelhauser, 2012).



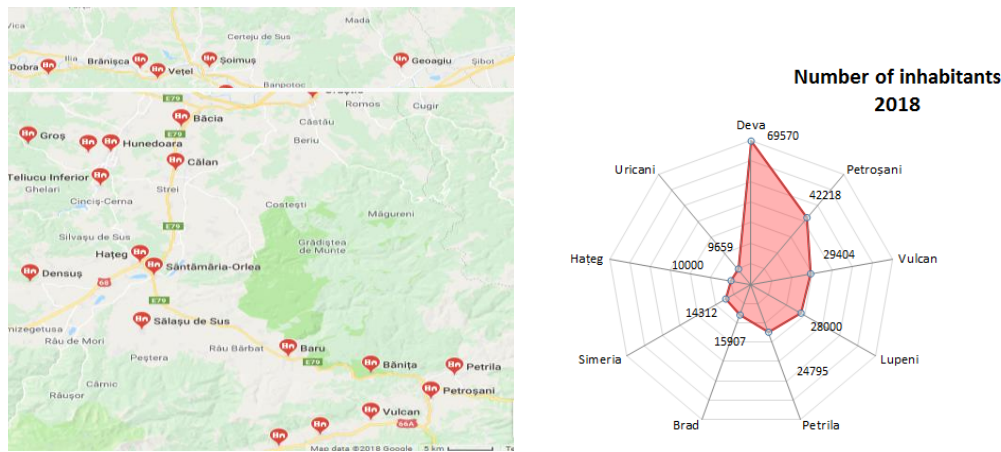


Fig. 5 (a) Territorial administrative units of Hunedoara County; ( b) The chart of the number of urban population

Data were collected from 11 territorial administrative units from Hunedoara County (Fig. 5a), but these are representative for the year 2018 IT level, because there were selected from the 14 cities and municipalities of the county, and represent 74% of the urban population.

## 5.2. Findings and discussions. Graphical results

The 9<sup>th</sup> pillar establishes the clear link between Technological readiness and availability of latest technologies. So in figure 5b we determined the numbers of used computers in TAUs of Hunedoara County and from which are servers (figure 5c).

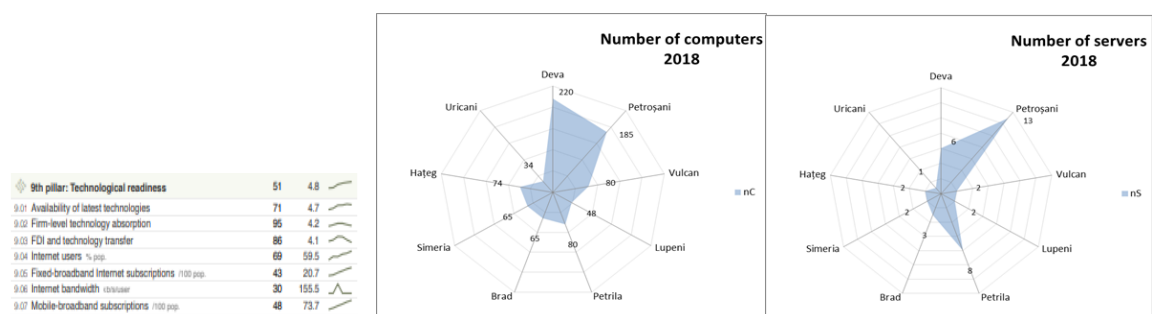


Fig. 5 (a). 9th pillar: Technological readiness; (b). Computers used in TAUs of Hunedoara County; (c). Servers used in TAUs of Hunedoara County.

Also, to another relevant question focused on the personalized access of the citizens to the public data, we observed that only 36% of TAU's are using the full benefit of the Internet. But the future is optimistic because 64% of the respondents consider that it will be useful to offer the personalized access for the public to data.

A first conclusion can be reached. Hunedoara County is prepared from the point of view of the IT infrastructure for the implementation of the Data Collection phase of an analytical dashboard. In addition, Petrosani through the presence of the trained personnel as well as the IT endowment from TAU's, can be the ramp of development of the following phases of the dashboard namely Data Processing and Data Analysing.

## 6. Conclusion

Currently, it is believed that a modern public sector is the one that provides opportunities for innovative information and information technology, accelerates strategic performance and human resources, allowing the administration to perform efficiently to raise living standards.

The quality of public administration is an important driver of national competitiveness. The conditions for an effective public administration are the focus on performance, the focus on quality services and products, institutional reorganization and adaptation, efficient human resource management and innovation of governance techniques and methods, including eGovernment.

Moreover, the tools currently used by Romanian public administration do not support a high public value of services and goods, leading to higher levels of bureaucracy and corruption. Therefore, it is necessary to improve all the constituent elements of the public sector so that it is able to fully support national and regional competitiveness, but economic growth as a whole.

## References

- Afonso, A., Fernandes, S., *Measuring local government spending efficiency: Evidence for the Lisbon Region*, Regional Studies. (2006).
- Allio, M.K. "Strategic dashboards: designing and deploying them to improve implementation", *Strategy & Leadership*, Vol. 40 Issue: 5, pp.24-31, <https://doi.org/10.1108/10878571211257159> (2012).
- Bizer, C., Boncz, P., Brodie, M. L., & Erling, O. The meaningful use of big data: Four perspectives — four challenges. *SIGMOD Rec.* 40(4), 56–60. <http://dx.doi.org/10.1145/2094114.2094129> (2012).
- Cleveland, W.S. Data Science: *An action plan for expanding the technical areas of the field of statistics*. *International Statistical Review* 69 (1), 21-26 (2001).
- Dawes, S. S., & Helbig, N. *Information strategies for open government: Challenges and prospects for deriving public value from government transparency*. *Electronic government* (pp. 50 – 60). Springer Dietrich, (2010).
- Edelhauser, E., Lupu Dima L *Management Information Systems. Past And Present in Romanian Organisations*, Paper presented at the 11<sup>th</sup> International Conference on Informatics in Economy IE 2012, Bucharest, Romania (2012).
- Edelhauser, E., Ionica, A. and Leba, M. "Modern Management Using IT&C Technologies in Romanian Organizations", *Transformations in Business & Economics* Volume: 13 Issue: 2B Pages: 742-759 (2014).
- Eckerson, W. W. *Performance dashboards: Measuring, monitoring, and managing your business*. Wiley. (2010).
- Few, S. *Information dashboard design*. O'Reilly (2006).
- Ganapati, S. *Use of dashboards in government-been there and done that* modified 12: 00, 11 Nov 2011 by admin|page history (2011).
- Harrison, T. M., & Sayogo, D. S. *Transparency, participation, and accountability practices in open government: A comparative study*. *Government Information Quarterly*, 31(4), 513–525. (2014).
- Janssen, M., & van den Hoven, J. *Big and open linked data (BOLD) in government: A challenge to transparency and privacy?* *Government Information Quarterly*, 32(4), 363–368. <http://dx.doi.org/10.1016/j.giq.2015.11.007> (2015).
- Janssen, M., Estevez, E., & Janowski, T. *Interoperability in big, open, and linked data—Organizational maturity, capabilities, and data portfolios*. IEEE Computer Society (2014).
- Janssen, M., Matheus, R., & Zuiderwijk, A. *Big and open linked data (BOLD) to create smart cities and citizens: Insights from smart energy and mobility cases*. *Electronic Government* (pp. 79–90). Springer. (2015).
- Matheus, R., Janssen, M., Maheshwari *Data science empowering the public: Data-driven dashboards for transparent and accountable decision-making in smart cities* Delft University of Technology, Faculty of Technology, Policy and Management, Jaffalaan 5, 2628 BX Delft, The Netherlands
- Ochrana, B - *Benchmarking as a Substitute for the Market Mechanism: Empirical Evidence for the Czech* [https://doi.org/10.1016/S2212-5671\(15\)01273-3](https://doi.org/10.1016/S2212-5671(15)01273-3) (2004).
- Plachy, B. L., Norton, M. F. *Analytics across the enterprise: How IBM realizes business value from big data and analytics*. IBM Press (2014).
- Tanzi, V. Schuknecht, L., Alphonso, A. Working Paper nr.242, European Central Bank. (2003). <http://reports.weforum.org/global-competitiveness-report-2015-2016/economies/#economy=ROU>
- <http://www3.weforum.org/docs/GCR2017-2018/05FullReport/TheGlobalCompetitivenessReport2017%E2%80%932018.pdf>



## Aspects Concerning the Quality of Management Projects Designed for Restructuring the Economy

Eugenia Jornea<sup>a\*</sup>, Eduard Edelhauser<sup>a</sup>, Amalia Furdui<sup>a</sup>

<sup>a</sup> University of Petrosani, Universitatii street, No. 20, Petrosani, 332006, Romania

---

### Abstract

Half a century ago, Hunedoara was one of the most industrialized county in the country, and the main cities of these county based their economy on large enterprises, the metallurgy and mining industries. Due to the dependence of the population on the extractive and metallurgy industry, this territory was identified as fragile area characterized by industrial decline. The statistics of the last years show that Hunedoara's County economy is 10 times weaker than in 1985. According to the "Projection of the main economic and social indicators in territorial profit until 2019", drafted by the National Prognosis Commission, Hunedoara County will have an economic evolution relatively positive. At the county level, it is necessary to develop a general medium-term development plan that would provide a starting point and to set out the development principles of Hunedoara County, namely by attracting investors, which can would contribute to the restructuring of the economy by replacing dependence on the mining industry as a result of creating a variety of sectors, businesses and qualifications. In order to achieve these objectives, an important role in the implementation of projects is the quality of management, which involves the processes necessary to ensure that the project will meet the needs for which it has been undertaken. Project quality management includes all the activities of the general management function that determine the quality policy, the objectives and responsibilities they implement within the quality system by means such as: quality planning, quality control, quality assurance and quality improvement.

*Key words:* organisational culture; improvement; management; performance; change.

---

### 1. Introduction

Project Management is defined by the Project Management Institute as implementing the project-specific knowledge, skills, tools and techniques to meet or exceed the expectations and requirements of those involved in a particular project (Oprea, 2011). Authors Kezsbom and Edward, believes that project management is a process that gives contemporary organizations the unique vehicle that will drive them to change. When it comes to defining project management, the same authors start from the idea that project management is a combination of people, processes, techniques and technologies needed to successfully complete projects / programs (Kezsbom and Edward, 2001).

Project management is a tool for planning, coordinating, realizing and controlling complex activities in modern industrial, commercial, social, cultural and political structures. It can be said that today project management has become an orientation for all organizations, both for the public sector and for the private sector. Project management tends to become the main form of existence in the economic environment (Dobrescu and Pavel, 2014).

As it is known, Hunedoara County was a county of superlatives. Unfortunately, its development was unbalanced. The entire county depended on the welfare of only two industries: the metallurgy industry and the mining industry. When these two industries collapsed, the entire county lost its economic base. That is why a method of economic re-balancing of the county must be considered so that it does not depend on such a small number of branches of the economy. For a balanced, harmonious development, it is necessary to design coherent programs to encourage the development of alternative branches of the economy ([http://winklergyula.ro/pdf/pdf\\_rmdsz.pdf](http://winklergyula.ro/pdf/pdf_rmdsz.pdf)).

---

\*Corresponding author. Tel.: +40784322291  
E-mail address: [jorneaeugenia@yahoo.com](mailto:jorneaeugenia@yahoo.com)

## 2. Analysis of the evolution of the main economic and social indicators in Hunedoara County

Hunedoara was, during 1950-1989, one of the most industrialized counties of Romania. Restructuring of the mining sector has led to the economic blockage of the entire area, as well as to the increase in the unemployment rate, because the area is a mono-industrial one. Now, the county through various actions, projects are trying to escape under the county label of the unemployed.

Workforce. The actual number of employees at the end of June 2018 was 114946 persons, 206 persons higher than in May and 3282 persons higher than in June 2017. The Table 1 represents „The actual number of employees“ at the end of June, 2018, according to statistical data provided by the National Statistics Institute of Hunedoara.

Table 1. The actual number of employees

The actual number of employees	June 2018	% in total
TOTAL COUNTY		
from which:	114946	100
agriculture and related services, forestry	3147	2.7
industry and construction	52175	45.4
Services	59624	51.9

Source: ([http://www.hunedoara.insse.ro/wp-content/uploads/2018/08/COMUNICAT\\_iunie2018.pdf](http://www.hunedoara.insse.ro/wp-content/uploads/2018/08/COMUNICAT_iunie2018.pdf))

In Table 2, according to the data of the County Agency for Employment (AJOFM) Hunedoara, the total number of unemployed in the county reached 6755 at the end of June of this year, of which 3234 are paid and 3521 are not paid. Thus, in the records of AJOFM Hunedoara the unemployment rate is almost 3.73%.

Table 2. Total number of unemployed registered in 2017 and 2018

Years	Total No. unemployed	Total No. unemployed paid	Total No. unpaid unemployed	Unemployment rate %	Female unemployment rate %	Male unemployment rate %
2018	6755	3234	3521	3,73	4,13	3,38
2017	7898	3248	4650	4,36	4,54	4,2

Source: (<https://www.anofm.ro/statistica>)

Lower unemployment, more companies, these are the results of the latest report of Hunedoara County Bureau of Statistics. In the figure below, we can see that the unemployment rate registered in 2017 compared to 2018 is lower by 0.63%.

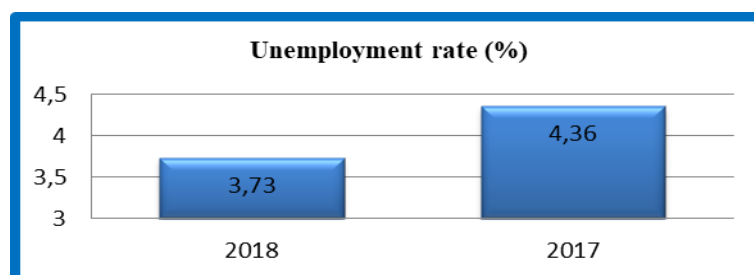


Fig.1. Unemployment rate 2017-2018

In Figure 2 is the total number of unemployed registered in 2017 and 2018, and there is a decrease in them from one year to another and we hope that this decrease will occur in the future as a result of the development of the business environment in Hunedoara County, funding opportunities, implementing projects to attract new technologies and equipment, and research and development activities, or increasing access to broadband and related services.

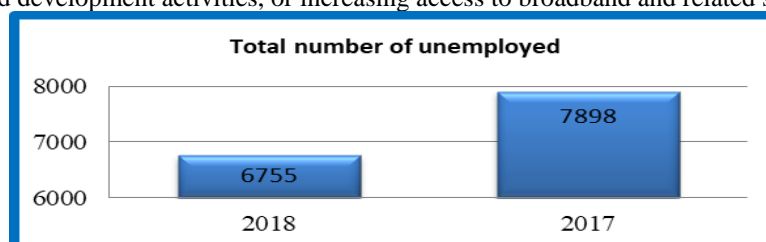


Fig. 2. Total number of unemployed 2017-2018

Industry. In Romania, in the years after the Revolution, about 1260 enterprises were closed, including several dozen enterprises in Hunedoara County. As the company is a basic link of the economy where the production of goods, the execution of some works or the performance of services according to the market requirements, their closure has led to an economic decline still felt to this day. Currently, 44298 companies are registered in Hunedoara County (<http://www.firme.info/hunedoara>). According to INS statistical data, industrial production in June was 8.6% lower than in May and 11.4% lower than in June 2017. In June 2018, the following developments were registered in June 2018, which we have represented in Table 3 and Table 4.

Table 3. Growth in industrial production, June 2018

Increases were recorded in the following branches:	-% -
Manufacture of textiles	+86.7
Manufacture of beverages	+86.1
Manufacture of other means of transport	+39.0
Manufacture of paper and paper products	+24.0
Manufacture of furniture	+18.4
Metal and metal products industry	+17.5
Manufacture of other non-metallic mineral products	+16.5
Other extractive activities	+16.0
Repair, maintenance and installation of machinery and equipment	+10.1

Source: ([http://www.hunedoara.insse.ro/wp-content/uploads/2018/08/COMUNICAT\\_iunie2018.pdf](http://www.hunedoara.insse.ro/wp-content/uploads/2018/08/COMUNICAT_iunie2018.pdf))

Table 4. Decline in industrial production, June 2018

Decreases were found in the branches:	-% -
Manufacture of motor vehicles	-40,6
Extraction of coal	-26,6
Manufacture of wearing apparel	23,8
Production and supply of electric and thermal energy	-22,3
Food industry	-16,8
Manufacture of footwear, travel goods and leather goods	-14,4
Manufacture of electrical equipment	-11,5

Source: ([http://www.hunedoara.insse.ro/wp-content/uploads/2018/08/COMUNICAT\\_iunie2018.pdf](http://www.hunedoara.insse.ro/wp-content/uploads/2018/08/COMUNICAT_iunie2018.pdf))

International commerce. In April 2018, goods were exported in the amount of 68339 thousand Euro, 15.7% less than in March 2018 and goods imported in the amount of 52136 thousand Euro, 17.7% less than in March 2018. The balance is 16,203 thousand Euro. During the first 4 months goods were exported amounting to 285826 thousand euro and goods imported in the amount of 221438 thousand euro were imported. The balance for the first 4 months is +64388 thousand euros.

Tourism. According to statistical data provided by the National Statistics Institute of Hunedoara, the number of tourists arrived in June 2018 was 16,726 (Table 5), with 1385 more than in May. The number of overnight stays in June was 32,624, 2637 higher than in May. The average number of nights per tourist was 2.0, the same as in May. For 6 months 2018 79503 tourists arrived, 12.4% more than in the first 6 months of 2017. The number of overnight stays in 6 months 2018 was 142,153, 0.3% lower than in the corresponding period of 2017.

Table 5. Arrivals in the tourism reception structures

Types of tourist accommodation structures	June 2018	% compared to the previous month	% compared to the corresponding month of 2017
TOTAL location, of which:	16726	109	102,1
Hotels	10242	107,9	95,2
Motels	438	99,8	151
Tourist villas	1865	109,1	117,6
Tourist cottages	440	99,1	143,3
Urban tourist boarding houses	1892	111,4	91
Rural tourist boarding houses	995	109	131,3

Source: ([http://www.hunedoara.insse.ro/wp-content/uploads/2018/08/COMUNICAT\\_iunie2018.pdf](http://www.hunedoara.insse.ro/wp-content/uploads/2018/08/COMUNICAT_iunie2018.pdf))

The net use index of accommodation places was 22.4% in June, 2.2% higher than in May. For the economic recovery at county level, it is necessary to elaborate a general medium-term development plan, 2018-2023, to ensure a starting point and to set out the principles of development of Hunedoara County.

The strengths of Hunedoara County, which would help to change the economic course, would be to attract attention to tourism development as a new sector of economic activity, to focus investments on business incubators and business parks, to encourage the private sector - to develop SMEs.

### 3. Analysis of the economic restructuring strategies of Hunedoara County

The development of Hunedoara County, supporting the economic environment, ensuring decent living conditions for the inhabitants and at the same time respecting the unique natural environment are complex objectives, and their realization depends on a whole range of factors and the assumption of responsibility by both the public sector institutions, private agencies or non-governmental actors. Hunedoara County has developed a Regional Development Plan, which aims to guide the economic, social, territorial, balanced development of the county during the period 2014-2020, establishing access to European funds, sources of public and private domestic financing, as well as those coming from from other categories of donors, in the current context of Romania's membership of the European Union. The Regional Development Plan responds to the socio-economic development needs of Hunedoara County being at the same time correlated with the European, national and regional guidelines. Thus, it provides all local actors with a common framework and direction for action - a coherent set of priorities and objectives that can channel individual efforts and act synergistically in the community's interest.

The strategic directions defined in the Hunedoara County Development Plan 2014-2020 include the continuation of the strategies for the period 2007-2013, which indicate eight axes covering a wide range of measures in various fields, namely:

- Transport and Energy Infrastructure,
- Economic Competitiveness,
- Tourism,
- Territorial Cooperation,
- Rural Development,
- Development of Human Resources and Social Services,
- The environment and
- Urban development.

In addition to the Hunedoara County Development Plan, in 2009 was developed the Strategy for accessing the community funds at the level of Hunedoara County 2007-2013, which proposes an action plan for obtaining European financing by prioritizing the portfolio of projects of the local public authorities and developing the capacity necessary for the management of relevant projects.

Given the importance of the availability of non-reimbursable EU funds during the analyzed period, the financing contracts signed at the Hunedoara County level in 2007-2013 amount to over 680 million Euros. They have made an important contribution to achieving the strategic objectives identified in the county development plan. The fundings accessed during the 2007-2013 financial year were mainly obtained through the Regional Operational Program (30.64% of the total), respectively in Figure 3 we have presented the rate of use of the European programs in Hunedoara County during the period 2007-2013 and we have the Sectoral Operational Program Environment (29.61%), the National Rural Development Program (16.86%), the Sectoral Operational Program Increase of Competitiveness (12.97%), the Sectoral Operational Program Human Resources Development (9, 88%) and the Administrative Capacity Development Operational Program (0.04%).

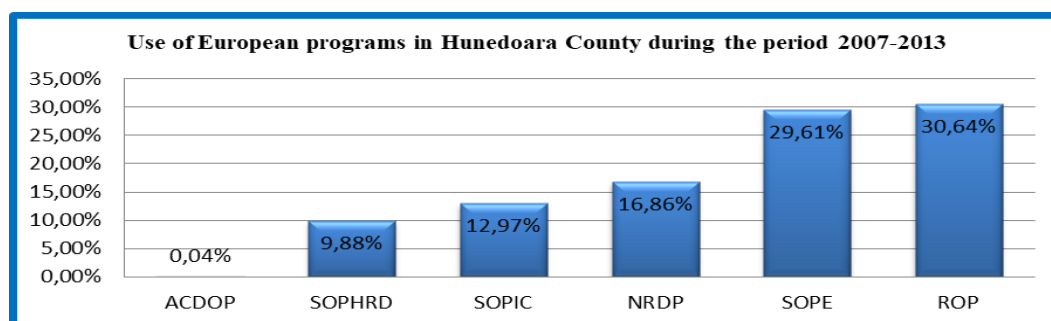


Fig.3. Use of European programs in Hunedoara County during the period 2007-2013

In the elaboration of the Hunedoara County Development Plan 2014 - 2020 were analyzed:

- Multiannual Financial Framework 2014-2020 of the European Union, Associated Financial Mechanisms or Partner of the European Union;
- Cohesion Policy 2014-2020 of the European Union;
- Financing programs of the Romanian Government;
- National Strategy for Sustainable Development of Romania;

- National Territorial Planning Plan;
  - Master Plan of Transport of Romania;
  - Western Regional Development Strategy 2014-2020;
  - West Region Regional Development Plan 2014-2020;
  - Waste Management Plan - Hunedoara County, approved by Decision no. 15/2015;
  - The Territorial Interurban Territory Arrangement Plan - Deva - Hunedoara - Simeria, approved by Decision no. 142/2010;
  - The tourism development strategy of Hunedoara County, approved by Decision no. 155/2010;
  - County Strategy for Child Rights Protection - Hunedoara County, approved by Decision no. 65/2014;
  - Master Plan on Extension and Modernization of Water Supply and Sewerage Systems in Hunedoara County by Decision no. 238/2014;
  - The strategy for accessing the community funds at the level of Hunedoara County in the period 2007 - 2013, approved by the Decision no. 38/2009;
  - Hunedoara County Development Plan 2007 - 2013;
  - National Program for Rural Development and Rural Development
- ([http://www.cjhunedoara.ro/documente/hotarari/2017/anexa%20hot%20131%20plan%20de%20dezv/SDJ\\_HD\\_rev\\_09.06\\_N.pdf](http://www.cjhunedoara.ro/documente/hotarari/2017/anexa%20hot%20131%20plan%20de%20dezv/SDJ_HD_rev_09.06_N.pdf))

In addition to the Hunedoara County Regional Development Plan, on July 12, 2018, Minister of European Funds, Rovana Plumb, presented the projects for the development of the Jiu Valley in Brussels.

The projects submitted to the European Commission for the development of the Jiu Valley are:

Transport infrastructure - opening of Jiu Valley:

- The road from Câmpu lui Neag to Herculan;
- Vâlcea-Voineasa-Petrila-Petroșani Road;
- DN66A - the connection of the cities of the Jiu Valley.

Jiu Valley Tourism Infrastructure:

- Jiu Valley ski area from East to West: Petrila, Petrosani, Vulcan, Lupeni;
- Museum, recreation, sports and adventure touristic complex "Retezat National Park" -Uricani.

Industrial development of the Jiu Valley:

- Industrial parks / business incubators - for all the localities in the Jiu Valley;
- Investments in the area's resources (coal and minerals - quartz).

The energy efficiency of Jiu Valley:

- Investments in the Jiu Valley district heating system by maintaining the production of coal, refurbishment;
- Thermal rehabilitation of blocks of flats;
- Rehabilitation of social housing in the Jiu Valley.

Support for the private environment Valea Jiului:

- Financing axis for the private sector - maximum 10% co-financing for job creation;
- Financing will target the areas of the Jiu Valley: rehabilitation / building of pensions / accommodation, agro-tourism; financing lines for processing wool, milk, meat, berries, mushrooms, wood, extraction of water;
- Start-up funding;
- Minimis aid for big investors.

Local development of Jiu Valley:

- Rehabilitation of small infrastructure for each locality (streets / sidewalks in former mining districts, parks, schools, etc.);
- Rehabilitation of public buildings, including those left in the mining and abandoned mining industry;

The social component of Jiu Valley (people and family in the spotlight):

- Social monitoring programs - social monitor employed at each town hall;

Ensuring the financing from the Romanian Government for co-financing projects from European and governmental funds accessed by the Jiu Valley.

Romania will also develop a strategy for implementing an appropriate integrated territorial investment instrument for the Jiu Valley region. In the same sense, the Ministry of Energy elaborated a draft Memorandum "The Hunedoara Energy Complex Company - Current Situation and Perspectives", to be promoted in the Government.

(<http://www.replicahd.ro/proiectele-pentru-valea-jiului-au-fost-prezentate-la-bruxelles/>)

#### **4. Conclusion**

If so far a number of development programs have been implemented in Romania, they have been selected in isolation, without an organic link between them and without an overall view. Hunedoara County faced some strange ideas, such as turning the Jiu Valley into a "tourism paradise" in just a few years. For this purpose, a number of tourist facilities have been created, but without a global vision.

For the harmonious development of the county, a holistic thinking is required, covering at the same time all the domains that are connected in the everyday life and which influence each other. Thus, we can not talk about infrastructure and environmental protection without talking about education, we can not talk about education without talking about transport infrastructure, we can not talk about tourism without environmental protection and a general landscape view of the area, etc. In life, all these elements are interconnected and mutually interrelated.

## **References**

- Dobrescu A., Pavel E., *Managementul Proiectelor Finantate din Fonduri Europene Pentru Perioada 2014-2020*, Editura Pro Universitaria, Bucuresti, (2014).
- Oprea D., *Managementul Proiectelor Europene*, FEEA Universitatea „Al.I.Cuza” Iasi, (2011).
- Kezsbom, D.S., Edward, K.A. – *The New Dynamic Project Management*, John Wiley & Sons, Inc., New York, (2001).
- \*\*\*[http://winklergyula.ro/pdf/pdf\\_rmksz.pdf](http://winklergyula.ro/pdf/pdf_rmksz.pdf)
- \*\*\*<https://www.anofm.ro/statistica>
- \*\*\*<http://www.firme.info/hunedoar>
- \*\*\*[http://www.hunedoara.insse.ro/wp-content/uploads/2018/08/COMUNICAT\\_iunie2018.pdf](http://www.hunedoara.insse.ro/wp-content/uploads/2018/08/COMUNICAT_iunie2018.pdf)
- \*\*\*[http://www.cjhunedoara.ro/documente/hotarari/2017/anexa%20hot%20131%20plan%20de%20dezv/SDJ\\_HD\\_rev\\_09.06\\_N.pdf](http://www.cjhunedoara.ro/documente/hotarari/2017/anexa%20hot%20131%20plan%20de%20dezv/SDJ_HD_rev_09.06_N.pdf)
- \*\*\*<http://www.replicahd.ro/proiectele-pentru-valea-jiului-au-fost-prezentate-la-bruxelles/>

# Corporate Social Responsibility in Polish Enterprises

Aleksandra Ptak \*

*Faculty of Management, Czestochowa University of Technology, ul. Armii Krajowej 19b, Czestochowa 42-200, Poland*

---

## Abstract

The concept of corporate social responsibility is nowadays treated as a business strategy. In the framework of all undertaken activities, the company takes into consideration the social interest and environmental protection issues, strengthening reputation, increasing the company's value, developing new products and services, as well as improving relations with stakeholders. The article presents the essence of corporate social responsibility and presents challenges and barriers to implementing CSR in Polish enterprises. It contains selected activities of Polish companies in the field of corporate social responsibility, and results of the research conducted among a group of Polish consumers, regarding their awareness and opinions in the field of CSR. The author tries to answer the question whether clients perceive social aspects of enterprises' operations.

*Keywords:* Corporate Social Responsibility, CSR, enterprise, consumers

---

## 1. Introduction

The term "responsibility" is clearly defined in the literature and defines the need to be responsible for one's behavior and its consequences (Drabik, Kubiak-Sokół, Sobol, 2017). The responsible person is characterized by the awareness of the inevitability of the obligation to bear the consequences of the actions taken.

Nowadays, companies have to be socially responsible to face growing competition on the market (Crane, Glozer 2016). Due to the easier access to information and growing social awareness, all unethical activities are often publicized by media, which results in negative consequences for the company's image. Enterprises, wanting to neutralize the negative impact of their activities on the environment and responding to the changing public awareness of recipients, began to consciously act for the benefit of the environment, seeing this as an opportunity to improve their image and increase competitiveness on the market (Bajdor, Lis, Nowodziński, 2016). Many of them pay attention not only to achieving the highest possible profit, but also take part in solving complex social and economic problems. Increasing expectations of the society in the field of corporate responsibility are caused by, among others, the increase in democratization of societies, aggressive marketing manipulating clients, increasing consumer awareness and development of consumer organizations, rapid processes of globalization of the economy and marginalization of local communities, the power of trade unions, economic scandals known through the media or degradation of the natural environment (Pawłowicz, Skriebkova, Wallis, 2009).

The concept of social marketing was created as a result of marketing transformations, as well as the ongoing process of environmental degradation and challenges faced by enterprises operating in the conditions of a growing global economy (Rabiański, 2011). The term "social marketing" was the first term of the modern concept of CSR and was used for the first time by Ph. D. Kotler and G. Zaltman in the early 1970s with reference to solving general social problems using commercial marketing tools.

## 2. The concept of corporate social responsibility

The concept of corporate social responsibility is a very broad and multidisciplinary concept (Garriga, Melé 2004). The complexity of the term was presented and published in 2010 in the Norm ISO 26000 *Guidance on Social Responsibility*. The standard defined by numerous experts cooperating with the International Organization for Standardization ISO, defines CSR as "the organization's responsibility for the impact of its decisions and actions (products, service, processes) on society and the environment" (ISO 26000, 2010) through transparent and ethical behavior that: contributes to the sustainable development and health and well-being of society, takes into account the

---

\* Corresponding author. Tel.: +48 343 250 489  
E-mail address: aleksandra.ptak@wz.pcz.pl



expectations of stakeholders, is compliant with applicable law and consistent with international standards of behavior, is consistent with the organization and practiced in its relations (Rojek-Nowosielska 2017; Bakanauskiene, Staniuliene, Zirgutis 2016).

As the author of the first CSR doctrine one considers A. Carnegie. According to him, it consists of two principles: the charity and trust. By charity one understands that the basic Christian principles were fulfilled, and from trust it resulted that the wealthy people became managers of the common good on behalf of other people. Carnegie spent a record amount of money on social goals and encouraged other wealthy people to fulfill their moral duty (Mazur-Wierzbińska, 2012). Modern understanding of corporate social responsibility was born in the United States and Great Britain in the 1950s (Łukasiewicz-Kamińska 2011). The necessity for conducting business considering the needs of the environment, for the first time was mentioned by H. Bowen in his publication *Social Responsibilities of the Businessman* (Krajewska 2008; McWilliams, Siegel, Wright 2006).

The definition of the World Business Council for Sustainable Development, which is an agreement developing cooperation between the business community, governments and non-governmental organizations for sustainable development, specifies that CSR is a continuous commitment of business to ethical behavior and to actions for economic development, while at the same time improving the quality of life of employees and their families, the local community and the whole society (Shpak, Stanasiuk, Hlushko, Sroka 2018; Pushkala 2016).

The definition disseminated by B. Roka, captures CSR as a social business, ie the process of learning about and incorporating changing social expectations into management strategies, as well as monitoring the impact of this strategy on the competitiveness of companies (Bernatt, Bogdaniecko, Skoczny 2011).

The corporate social responsibility strategy is a basket of activities in many areas. The material scope of corporate social responsibility includes, among others: compliance with legal norms, philanthropy and development of the local community, environmental protection, sustainable development, human rights, employee rights, market relations, corruption, corporate governance and animal rights (Blowfeld, Murray 2008; Nehru 2016). An important opportunity for the development of corporate social responsibility may be the development of modern communication technologies, and mainly the resulting change in the way the information is disseminated.

### 3. Implementation of CSR principles in Polish enterprises - challenges and barriers

In Poland, the CSR concept is increasingly used in enterprise strategies. The increase in the involvement of Polish units in this area is evidenced by, among others, the increasing number of companies that present their achievements in the annual Responsible Business in Poland report prepared by the Responsible Business Forum, which is a summary of all CSR activities. The scope of this year's topics is very wide: business and human rights, business involved in humanitarian aid, effectiveness of measuring CSR, diversity, responsible universities or closed circuit business. Referring to the results of the report from 2017, it was recorded:

- 1190 good business practices in Poland implemented in 2017, including 639 new practices and 551 long-term practices (published in previous editions of the Report)
- an increase in the number of apprenticeships by as much as 330
- 13 articles on trends in corporate social responsibility
- 177 companies have reported practices, including 50 SMES.

Invariably from the beginning of the issuance of the report, the most practices, both new and long-term ones, concern the area of social involvement, along with the development of the local community and the second area of work experience in this respect. The area in which many practices are published every year is the area of the natural environment - in this area the number of long-term practices, that is activities that are more than a one-off action, has increased.

According to the Ranking of Responsible Companies 2018, containing the listings of the largest companies in Poland assessed in terms of the quality of corporate social responsibility management, the highest places were taken by: Polpharma Schenker Sp. z o.o., Polska Grupa Energetyczna, Bank BGŻ BNP Paribas and Coca-Cola HBC Polska. In the banking, financial and insurance sector the most distinguished are: Bank BGŻ BNP Paribas, ING Bank Śląski and Bank Zachodni WBK. In the category of consumer goods and pharmacy, the first three places were taken by: Polpharma, Coca-Cola HBC Polska and CCC SA. In the Fuel, energy and mining category, the first positions were taken by: Polska grupa Energetyczna, Grupa LOTOS SA and Polskie Sieci Elektroenergetyczne SA. In the Industrial production category, the following were distinguished: Grupa Azoty, Lafarge Polska and Grupa Velux and SITECH Sp. z o.o. ex aequo. In the Services, trade and transport category, the first three places were taken by: Schenker Sp. z o.o., Carrefour Polska Sp. z o.o. and Tesco Polska.

In 2014, as an auxiliary body of the Minister of Economy in Poland, the Team for Corporate Social Responsibility was established. As the part of the team's work, the challenges for CSR for the years 2014-2020 were defined:

- for environmental protection: reducing gas emissions, responsible waste management, responsible wastewater management, reducing energy consumption and water consumption
- on the issue of social policy: recognizing the importance of diversity in the workplace, caring for employees' health, programs facilitating the reconciliation of work and family life, respect for human rights



- in terms of social economy: activities of Social Economy Support Centers, supporting social entrepreneurship
- on the issue of senior policy: activities for the elderly in local communities, care for retired employees, mentoring programs in companies.

Among the barriers that hinder or prevent Polish enterprises from implementing the corporate social responsibility strategy, it should be mentioned above all (Bachnik 2017): insufficient knowledge of Polish managers regarding ethics in business and the possibility of applying the principles of social responsibility as a compact business strategy, economic conditions resulting from the lack of capital and poorly developed consumer movement.

#### 4. The research methodology and the research results

The purpose of the conducted research was to determine awareness and opinions of consumers on corporate social responsibility in Polish enterprises.

The research was conducted in April and May 2018 among students of Czestochowa University of Technology. The questionnaire consisted of 9 questions, of which the first three concerned gender, age of the respondent and type of studies.

It was the one-off survey, the questionnaire had a form of paper, and it was handed over to fill by the respondents. All the survey questions were closed questions. All of them were of single choice. All of received questionnaires were filled out correctly.

The tested group consisted of  $n = 209$  students (113 women and 96 men) of two fields of study at the age of 18 to 46. They were students of 1st degree studies and 2nd degree studies, studying in full-time and part-time. The highest percentage of respondents were students of full-time studies (62%) and students of first-degree studies (89%). 38% of them were part-time students, and 11% were students of the second degree studies.

Fig. 1 refers to the knowledge of the concept of corporate social responsibility

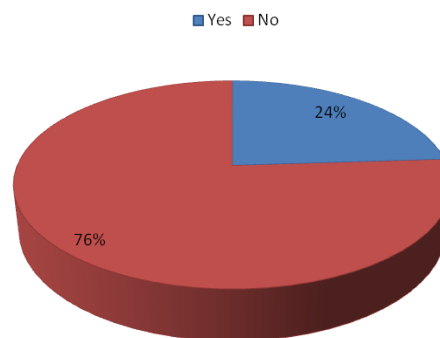


Figure 1. Have you ever heard about Corporate Social Responsibility (CSR)?

Source: Own work

As it is shown in Figure 1, 76% of surveyed stated, that they do not know the concept of corporate social responsibility, 24 % of respondents have heard of CSR.

Fig. 2 concerns the purpose for which (in the consumers' opinion) companies engage in social activities

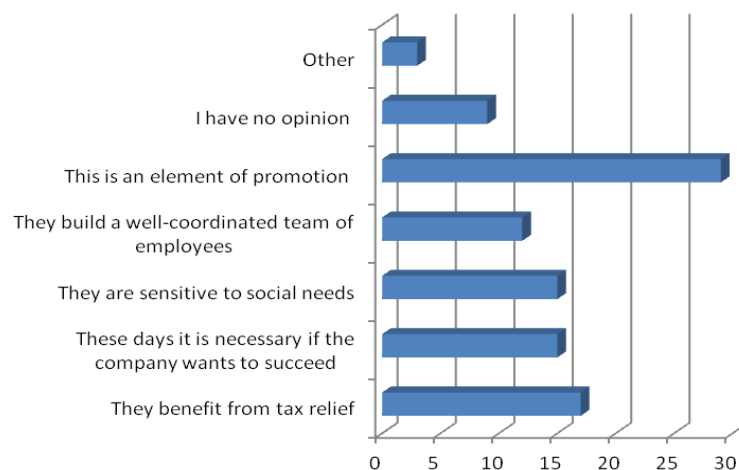


Figure 2. Why do you think companies are involved in social activities?

Source: Own work

The next question was on the knowledge of any socially responsible company. The vast majority, because as many as 93% of students, does not know any socially responsible company. The remaining 7% of respondents declared they know the socially responsible company. Among the responses received, Coca-Cola Hellenic Poland, BGŻ BNP Paribas, were listed.

As it is shown in Figure 2, 29% of respondents claim that the main reason for engaging companies in social activities is their promotion. 17% of surveyed are convinced that the companies are involved in social activities, because they benefit from tax relief. As many as 15 % of respondents believe that such activities are necessary if the company wants to succeed or the company is simply sensitive to social needs. 3% of surveyed chose the answer "Other", one person from his group of respondents is of the opinion that this kind of activities aims to divert public attention from breaking the law in companies.

The next question concerns whether or not, the companies should consider issues related to the environment in their daily activities

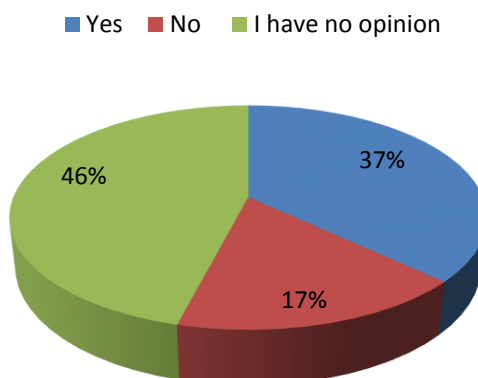


Figure 3. Do you think that companies should consider environmental issues in their daily activities?  
Source: Own work

As it is apparent from Figure 3, vast majority of respondents (45%) does not have opinion on the subject of whether companies should introduce environmental activities to their everyday activities. In turn, 37% of surveyed students believe that such actions should be taken.

Figure 4 refers to the question whether the fact, that company is socially responsible would affect the choice of its products

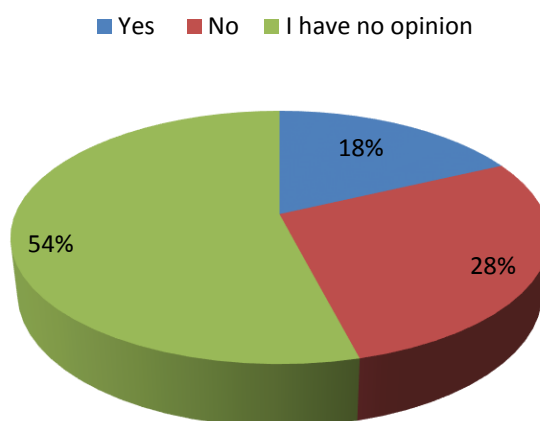


Figure 4. Does the information on the company's social and environmental activities have an impact on your choice of its products?  
Source: Own work

The data presented in Figure 4 show that slightly more than half of the respondents have no opinion on whether the fact that the company has environmental and social activities could affect the selection of this company's product. Only 18% of surveyed declare that such actions of the company would affect their purchasing decisions.

The next survey question is whether the person would be willing to pay more for the product if the company from which he would buy it, would take care of employees and be environmentally friendly.

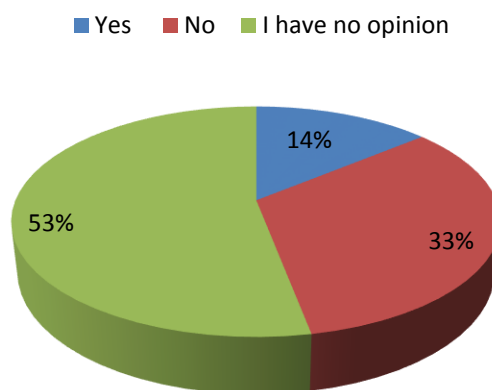


Figure 5. Would you pay a higher price for the product knowing that the company cares about the rights of employees and is environmentally friendly?

Source: Own work

As shown in Figure 5, most of respondents have no opinion on whether they would be willing to pay more for a product if they knew that the company from which they buy cares about the rights of employees and shows activities that are environmentally friendly. As much as 33% of students are of the opinion that this would not have any impact on their purchase decision.

## Conclusion

Some enterprises introduce into their activity the full strategy of corporate social responsibility and are taking into account all its areas. Also, stakeholders are increasingly expecting an active attitude and full involvement of the organization in social issues. Polish organizations are increasingly willing to implement the corporate social responsibility strategy. Surely, entrepreneurs have noticed, that thanks to the adoption of the strategy that takes into account the needs of stakeholders, it is easy to build the positive image and the competitive advantage.

The analysis of the results of the survey, conducted among students of the Management Faculty of Czestochowa University of Technology, shows that corporate social responsibility is for the overwhelming majority of them not-quite-known concept. Most of the respondents omit the area of corporate social responsibility in daily choices. Small part of respondents admits that they heard about corporate social responsibility, but again a small percentage of these people could point out socially responsible companies. This situation indicates that activities of companies within the framework of the CSR strategy are very poorly identified with the companies themselves and are perceived by consumers as an excuse to create a promotional campaign or the use of tax reliefs.

## References

- Bachnik M., CSR w praktyce polskich przedsiębiorstw : korzyści i bariery, *Handel Wewnętrzny*, no 3, vol. 2, (2017).
- Bajdor P., Lis T., Nowodziński P., Corporate Social Responsibility Politics in Small and Medium-sized Companies from Poland, *The International Academic Forum (IAFOR), The Asian Conference on Sustainability, Energy & the Environment 2016*, Kobe, Japonia (09 do 12 czerwca 2016 r.), Nagoya, (2016).
- Bakanauskienė I., Staniulienė S., Zirgūtis V., Corporate Social Responsibility: The Context of Stakeholders Pressure in Lithuania, *Polish Journal of Management Studies*, 13 (1), (2016).
- Bernatt M., Bogdaniecko J., Skoczny T., *Společna odpowiedzialność biznesu. Krytyczna analiza*, WN WZ UW, Warszawa, (2011).
- Blowfield M., Murray M., *Corporate Responsibility a Critical Introduction*, Oxford University Press, 2008
- Crane A., Glozer S., Researching corporate social responsibility communication: themes, opportunities and challenges, *Journal of Management Studies*, Vol. 53, Issue 7, (2016).
- Drabik L., Kubiak-Sokół A., Sobol E., *Słownik Języka Polskiego*, PWN, (2017).
- Effective Public Relations, *Komunikacja działań CSR w Polsce*, [www.effectivepr.pl/](http://www.effectivepr.pl/)
- Garriga, E. & Melé, D., Corporate Social Responsibility Theories: Mapping the Territory, *Journal of Business Ethics*, (2004).
- ISO 26000, *Guidance on social responsibility*, (2010).
- Krajewska A., *Společna odpowiedzialność biznesu CSR*, <http://archiwum.pdf.edu.pl/PDF/1329832181.pdf>

- Łukasiewicz-Kamińska A., Społeczna odpowiedzialność przedsiębiorstwa finansowego, Difin, Warszawa, (2011).
- Mazur-Wierzbicka E., CSR w dydaktyce, czyli jak uczyć studentów społecznej odpowiedzialności, Stowarzyszenie Kreatywni dla Szczecina, Szczecin, (2012).
- McWilliams A., Siegel D. S., Wright P. M., Corporate social responsibility: Strategic implications, *Journal of Management Studies*, (2006).
- Nehru R. S. S., Corporate Social Responsibility (CSR) & Education for Sustainable Development, *International Research Journal of Engineering, IT and Scientific Research*, Vol. 2, Issue 3, 2016
- Pawłowicz I. A., Skriebkova O., Wallis A., Społeczna Odpowiedzialność Przedsiębiorstw, *Zeszyt Naukowy WSOTiH*, nr 1, (2009).
- Pushkala M., Corporate Social Responsibility Initiatives and Employee Perspectives in UAE, *Polish Journal of Management Studies*, 14 (2), (2016)
- Rabiański R., Biznes odpowiedzialny społecznie. Zagadnienia, korzyści, praktyki, opracowanie w ramach projektu „Społecznie odpowiedzialny biznes – transfer wiedzy w oparciu o sieć CIAM” finansowanego przez Fundację Inicjatyw Innowacyjnych z Krakowa oraz Uniwersytet Stavanger z Norwegii, 2011, <http://www.ciam.fii.org.pl/wp-content/uploads/2011/01/Podrecznik-CSR.pdf>.
- Ranking Odpowiedzialnych Firm 2018, <http://rankingodpowiedzialnychfirm.pl/2018/06/ranking-odpowiedzialnych-firm-2018-wyniki/>,
- Rojek-Nowosielska M., Definicja CSR Według Normy ISO 26000 a Praktyka Gospodarcza, *Ruch Prawniczy, Ekonomiczny I Socjologiczny*, Rok LXXIX , zeszyt 3, (2017).
- Shpak N. O., Stanasiuk N. S., Hlushko O. V., Sroka W., Assesment of the Social and Labor Components of Industrial Potential in the Context of Corporate Social Responsibility, *Polish Journal of Management Studies*, 17 (1), (2018).

# Innovation of the Product as a Significant Factor in the Concept of the Development of a Toy Industry Enterprise

Agnieszka Noga \*

*Faculty of Management, Czestochowa University of Technology, ul. Armii Krajowej 19b, Czestochowa 42-200, Poland*

---

## Abstract

The paper presents the results in the field of evaluating the importance of product innovation in the concept of development of the toy manufacturing company. In the survey, opinions of production employees on the importance of seven factors of the company's development concept, among which the examined factor was found, were obtained. The company under study was presented. The author has made a presentation of the audited company. The research methodology (BOST survey) and the structure of the group of production employees of the examined company was presented to determine a typical respondent participating in the research. For the purposes of this paper, the analysis of the numerical and percentage structure of subjective assessments of factors as well as the analysis of the statistical significance of the variation of average scores was made. Combinations of various interpretations of graphical results are presented. In the surveyed company, the most important factors determining the concept of its development were: customer welfare and product innovation, what is confirmed by the structured summary of important factors.

*Keywords:* Innovation, manufacturing company, development

---

## 1. Introduction

Enterprises have to intensively create and develop their own productive potential to act quickly, flexibly and effectively in a market economy where competition is the primary economic phenomenon. These requirements for development and adaptation to the requirements of the environment make it necessary to innovate in various spheres of the company's functioning. The word innovation is derived from the Latin *innovatio*, meaning the creation of something new. This is not only about technical and technological, but also about socio-organizational innovations, and thus the sphere of management, which will allow for quick response and adaptation of own possibilities to the challenges posed by the competition (Mikołajczyk, 2002).

The aim of the research was to show how important in the concept of enterprise development, in the opinion of the company's employees, is product innovation.

## 2. Literature review

Every change undertaken in the enterprise has its main goal - the development of this enterprise, and therefore the profit and multiplication of capital. Thanks to the introduced changes, the companies improve product quality and competitiveness, because they increase the range, "rejuvenate" products and processes, and as a result increase their production capacity, reduce labor costs, etc. Companies can introduce changes by introducing innovations (Ali Taha, Sirkova, Ferencova 2016). Innovations can take different forms, but they always remain a decisive factor in the development of the company (Mirski 2014). There are many definitions of innovations in the literature in which the determinants of this category are mentioned (Krawczyk-Sokołowska 2012, Mirski 2014). One of the types of innovation are product innovations. These are changes consisting in a significant improvement of technical parameters, components and materials as well as functionality of the product already produced by the company (Kalinowski 2010,

---

\* Corresponding author. Tel.: +48 343 250 489  
E-mail address: agnieszka.noga@wz.pcz.pl

Kościelniak 2014). Product innovation, we can also call the introduction of completely new products to the market, the expansion of the product mix. This type of innovation affects the customer the most, because it meets his requirements and satisfies the needs. The potential consumer receives this type of innovation best, because the company provides the new or improved product or service, which increases customer satisfaction (Kalinowski 2010).

### 3. Research method

#### 3.1. Characteristics of the examined enterprise

The surveyed company exists on the Polish market for twenty-eight years and produces doll strollers, mainly for the domestic market (since 2010 it has opened to the Eastern European market, especially Russia). In the assortment, there are 15 types of strollers for dolls, which differ from each other with: the number of functions, own weight, colors and sizes. The company manufactures strollers based on materials from renowned domestic and foreign companies (textiles: Polish and Italian, powder paints: German and Spanish).

#### 3.2. The method for obtaining the results

The research was carried out using the BOST survey - Toyota management rules in questions (Borkowski S. 2012a). The name "BOST" comes from the first two letters of the name and surname of the author and is legally protected (Borkowski S. 2012b). The core of the BOST method are the Toyota management rules (Olejnik 2015), which are divided into sections, which is directly related to the structure of the Toyota road model described in the guiding works (Liker J.K. 2005, Liker J.K., Meier D. 2006). The BOST survey provides two groups of variables: an independent variable - the personal characteristics of the respondents and a dependent variable - an assessment of the validity of factors that describe Toyota's management principles. The structure of the survey consists of areas, each of them deals with a characteristic issue related to one of the 14 Toyota management rules (Noga, Ptak 2018). The study concerns two areas of the survey: the area, which set of factors describes Toyota's management principle 1 and the area describing the personal characteristics of respondents. The BOST survey (Borkowski S. 2016) is the measuring tool that has an ordinal scale, according to which respondents rank the importance of the described factors. Obtained results are subject to verification, statistical analysis and rating of assessments in a numerical or percentage system.

The study was conducted at a time. The survey questionnaires were in paper form and were provided to employees (respondents) to be completed. All questionnaires were completed correctly. By completing the questionnaire, the employee provides important information about the company under study. It helps managers to respond to the current state of processes taking place in it. By conducting surveys, one can determine the condition of the company.

#### 3.3. Characteristics of the surveyed group of employees

First, the characteristics of respondents were made due to their personal characteristics such as gender, education, work experience, mobility and mode of employment. This is an important element in the analysis of subjective assessments of factors defined in the questionnaires. Each of the six distinguished features in the survey has several variants: gender MK (2), education WE (4), age WI (8), seniority SC (8), mobility MR (6), mode of admission to work TR (3). Three characteristics: gender, education and the work admission mode have descriptive characteristics and the remaining, numerical ones (Borkowski S. 2016). Table 1 presents results regarding the characteristics of respondents collected in the survey.

Symbol	Marking of features and their percentage characteristics					
	MK	WE	WI	SC	MR	TR
1	53	38	22	34	38	63
2	47	41	28	19	22	13
3		9	28	16	22	25
4		13	6	6	6	
5			3	9	3	
6			0	3	9	
7			3	6		
8	32			6		

Table 1. Features of respondents. Percentage characteristics

Source: Own work based on (Borkowski S. 2013)

The results presented in Table 1 indicate that 53% of the respondents are men and 47% women. People who work in the enterprise in most cases have a minimum secondary education. The largest group of employees (28%) are people aged 31-40 and 41-50. In the enterprise, the most of employees - 34%, are people with five years of work experience,

while 6% of employees have a job seniority of over 36 years of work. It is also the longest job seniority recorded during the study.

### 3.4. Presentation of results

In the surveys, opinions of production employees on the importance of seven factors of the company's development concept, among which the examined factor was found, were obtained (IP). Respondents had to decide **which factors determine the company's development concept**:

DK	Customer's good
IP	<b>Product innovation</b>
WK	Partnership with collaborators
ZP	Trust in relationships with employees
SP	Self-reliance and responsibility of employees
RT	Technology development
PR	Care of the company's culture

The question was rated on a scale from 1 to 7, where 7 was the most important factor, while 1 was the least important factor. Regarding Toyota's management principle 1, the question was chosen to check which factors have a decisive impact on the development of the company. This was dictated by their compatibility with Toyota's principles section one (Liker J.K. 2005) entitled: „Far-reaching concept”.

Figure 1 presents obtained results, in the form of a numerical statement of the validity of factors defined in the analyzed part of the survey.

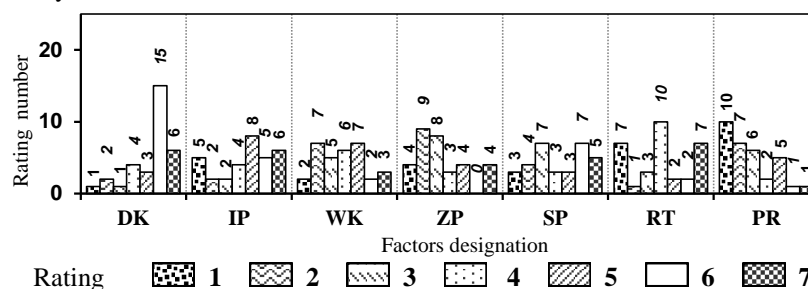


Fig. 1. Analysis of the distribution of grades for the factors of the selected survey area.

Source: Own study

When analyzing Figure 1, it is worth paying attention to the distinctive, highest bar, indicating the highest number of ratings (15) with the value of "6" for the customer's good factor (DK). However, the highest number (10) of the lowest "1" ratings was given to the factor: corporate culture care (PR).

This type of survey data set is the basis for determining the percentage structure of assessments, which is presented in Figure 2.

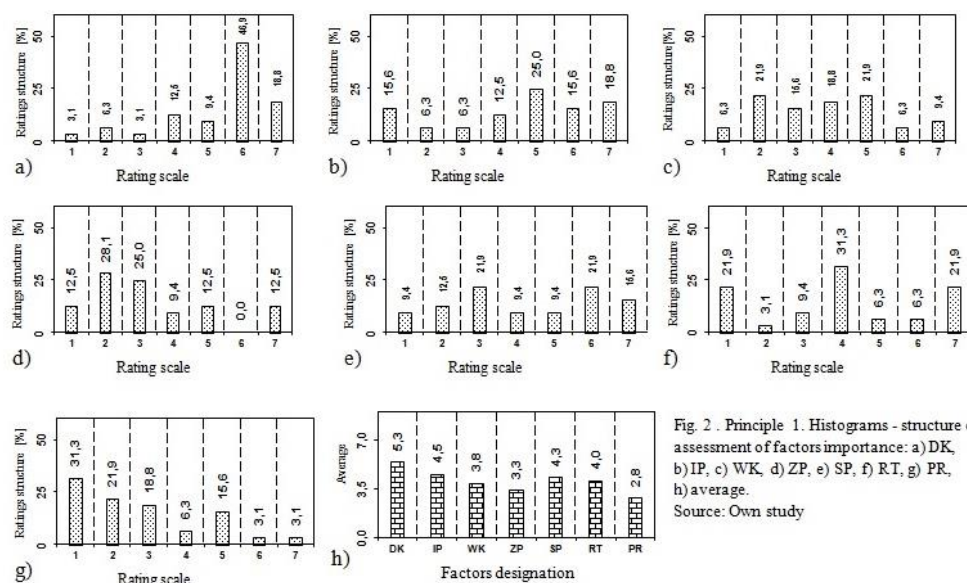


Fig. 2. Principle 1. Histograms - structure of assessment of factors importance: a) DK, b) IP, c) WK, d) ZP, e) SP, f) RT, g) PR, h) average.

Source: Own study



Analysis of the percentage data on histograms (Figure 2) allows the creation of further drawings and statistical analysis.

## 4. Results description

### 4.1. Assessment of significance of medium differences

The statistical average variation survey concerns seven factors describing Toyota's management principle 1. The comparative analysis of the average variation was calculated based on the student's test (Ostasiewicz S., Rusnak Z., Siedlecka U. 2001). Table 3 presents the results of the comparative analysis. The value of the correlation coefficient calculated from the survey results was adopted as the measure of significance of differentiation. The obtained value was compared with the critical value for a given probability level for a given number of measurements. Table 2 contains characteristic elements, i.e. seven factors describing Toyota management principle 1, test, and critical values for individual materiality levels  $\alpha$  ( $\alpha$  are respectively 0,05; 0,1; 0,2). Analyzing the content of such a tabular system consists of comparing the size of the test, for the relevant factors, with the critical values of the  $\alpha$  coefficient. If the critical value is lower than the test value, it means that there is a significant variation in the averages (in the table "yes")

Table 2 . The results of significance analysis varied in average of the validity ratings of selected factors

Marks		IP	WK	ZP	SP	RT	PR
DK	test	1,91	3,63	4,74	2,43	2,79	6,28
	$\alpha = 0,05$	no	yes	yes	yes	yes	yes
	$\alpha = 0,1$	no	yes	yes	yes	yes	yes
	$\alpha = 0,2$	no	yes	yes	yes	yes	yes
IP	test	E6	1,32	2,38	0,43	0,83	3,63
	$\alpha = 0,05$		yes	yes	no	no	yes
	$\alpha = 0,1$		yes	yes	no	no	yes
	$\alpha = 0,2$		yes	yes	no	no	yes
WK	test		1,19	0,87	0,39	2,54	
	$\alpha = 0,05$		no	no	no	yes	
	$\alpha = 0,1$		no	no	no	yes	
	$\alpha = 0,2$		no	no	no	yes	

Marks		IP	WK	ZP	SP	RT	PR	
ZP	test	1,96	1,96	1,64	1,28	1,95	1,44	1,26
	$\alpha = 0,05$					no	no	no
	$\alpha = 0,1$					yes	no	no
	$\alpha = 0,2$					yes	yes	no
SP	test	yes - significant differentiation				0,42	3,21	
	$\alpha = 0,05$					no	yes	
	$\alpha = 0,1$					no	yes	
	$\alpha = 0,2$					no	yes	
RT	test	no - irrelevant differentiation					2,63	
	$\alpha = 0,05$						yes	
	$\alpha = 0,1$						yes	
	$\alpha = 0,2$						yes	

Source: Own work based on (Borkowski, Sygut 2014)

Table 2 shows, that for the factor - the good of the customer (DK) the average difference in seventeen cases was recorded at all  $\alpha$  levels, in the following order: five times at  $\alpha = 0.05$  and six times for  $\alpha = 0,1$  i  $\alpha = 0,2$ .

### 4.2. Building the importance series of the considered factors

Based on Figure 1 and 2, series of validity of the analyzed factors describing Toyota management principle 1 were created.

They are presented as follows:

- for assessment "1"  $PR > RT > IP > ZP > SP > WK > DK$  (1)
- for assessment "2"  $ZP > PR > WK > SP > DK > IP > RT$  (2)
- for assessment "3"  $ZP > SP > PR > WK > RT > IP > DK$  (3)
- for assessment "4"  $RT > WK > DK > IP > SP > ZP > PR$  (4)
- for assessment "5"  $IP > WK > PR > ZP > DK > SP > RT$  (5)
- for assessment "6"  $DK > SP > IP > RT > WK > PR > ZP$  (6)
- for assessment "7"  $RT > DK > IP > SP > ZP > WK > PR$  (7)

From figure 1 and 2, regarding the assessment of "1", it appears that the factor - corporate culture care (KW) has the least importance for the respondents (first place in the row - formula (1)). The factors: customer's good (DK), product innovation (IP) and technology development (RT) are recognized by employees of the surveyed company as the most important in the implementation of the production process of toys.

The client's good factor (DK) received the highest score of "6" (46.9%), the innovation of the product factor received the highest score of "5" (25%), and the technology development factor (RT) received the highest number of ratings "7" (21.9%). These factors take the first place in the appropriate series of importance: (5), (6), (7). The average values of the assessment for individual factors additionally emphasize that in the opinion of the respondents, for the development of the company, the most important are: customer's good (DK) and product innovation (IP). The least important is corporate culture care (PR). The above is shown in Figure 2h and in the series of validity of factors' assessments due to their average values (formula 8).

$$DK > IP > SP > RT > WK > ZP > PR \quad (8)$$



## 5. Conclusion

BOST research was used to determine the significance and place in a series of validity factors of the concept of development of a company producing toys according to the product innovation factor. Information was obtained from the employees of the examined company. In the opinion of the respondents, for the development of the company, the most important are: customer's good (DK) and product innovation (IP), the least important is care of the company's culture (PR). The simultaneous orientation of the company to the client's good and product innovation has a positive impact on the company's perception and bodes well for achieving success in the market over a longer period of time.

The introduction of innovative technologies and production processes, and ultimately ensuring innovation (Cruz, Paulino 2013, Bajdor, Lis, Ptak 2016) of products is a strategic goal of the company's operation (Wojnicka-Sycz, Sycz 2016). On the other hand, the involvement of all employees (Johansen et al., 2015) participating in the company's activities and orientation on bottom-up activities (eg by training employees physically implementing processes) (Mom, Van Den Bosch, Volberda, 2007) will ensure faster introduction of product innovation (Glor 2014). Teamwork and customer welfare are deeply embedded in philosophy (Garcia, Maldonado, Alvarado & Rivera 2014, Schwarz, Nielsen, Stenfors-Hayes; et al 2017), from which the BOST method used in the research derives. The Japanese, who have succeeded based on this philosophy, are still an example to follow for success for companies around the world (Schonberger, 2007).

## References

- Ali Taha V., Sirkova M., Ferencova M., The Impact of Organizational Culture on Creativity and Innovation, Polish Journal of Management Studies, Vol. 14, No 1, pp. 7-17 (2016).
- Bajdor P, Lis T, Ptak A., The role of information/knowledge flow in the clients' purchasing decisions. 3rd Business & Management Conference, Lisbon, 22 Marzec 2016, Lizbona (2016)
- Borkowski S., Dokumenty zawierające wymyślony termin (TOYOTARYZM) oraz zawierające nazwę i strukturę opracowanej metody (BOST). Potwierdzenie daty: "AAK" KANCELARIA PATENTOWA s. c., Częstochowa, (2012a).
- Borkowski S., Zasady zarządzania Toyoty w pytaniach. Wyniki badań BOST, Wydawnictwo Menedżerskie PTM, Warszawa, (2012b).
- Borkowski S., Przydatność metody BOST do oceny funkcjonowania przedsiębiorstwa, Wydawnictwo Stowarzyszenia Menedżerów Jakości i Produkcji, Częstochowa, (2013).
- Borkowski S., Potencjał naukowy Toyotaryzmu i metody BOST. Polski Instytut Jakości sp. z o.o. Warszawa, (2016).
- Borkowski S., Sygut P., Toyotaryzm. Znaczenie innowacji w metodzie BOST, Oficyna Wydawnicza Menedżerów Jakości i Produkcji, Częstochowa, (2014).
- Cruz S., Paulino S., Public Service Innovation and Evaluation Indicators, Journal of Technology, Management & Innovation, Special Issue ALTEC: Social and Sustainable Project, Knowledge and Innovation Management, Vol. 8 (2013).
- García J., Maldonado A., Alvarado A. and Rivera D., Human critical success factors for kaizen and its impacts in industrial performance. The International Journal of Advanced Manufacturing Technology70(9–12): 2187–2198, (2014).
- Glor E.D., Studying the Impact of Innovation on Organizations, Organizational Populations and Organizational Communities:A Framework for Research, The Innovation Journal: The Public Sector Innovation Journal, Volume 19 (3), (2014).
- Johansen S., Olsen, T., Solstad, E., Torsteinsen, H., An insider view of the hybrid organization: How managers respond to challenges of efficiency, legitimacy and meaning. Journal of Management & Organization, vol. 21, Issue 6, pp. 725-740, (2015).
- Kalinowski T.B., Innowacyjność przedsiębiorstw a systemy zarządzania jakością, Wolters Kluwer Polska Sp. z o.o., Warszawa. s. 14, 16, 24, 26, 45, 118, 123, (2010).
- Kościelniak H., An Improvement of Information Processes in Enterprises – The Analysis of Sales Profitability in the Manufacturing Company Using ERP Systems, Polish Journal of Management Studies, Vol. 10, No 2, pp. 65-72 (2014)
- Krawczyk-Sokołowska I., Innowacyjność przedsiębiorstw i jej regionalne uwarunkowania, Wydawnictwo Politechniki Częstochowskiej, Częstochowa. s. 11-32, ,(2012).
- Liker J.K., Droga Toyoty. 14 zasad zarządzania wiodącej firmy produkcyjnej świata, MT Biznes, Warszawa, (2005).
- Liker J.K., Meier D., The Toyota Way fieldbook —A practical guide for implementing Toyota's 4Ps. Mc., . (2006).
- Mikołajczyk, Z., Techniki organizatorskie w rozwiązywaniu problemów zarządzania, Wydawnictwo naukowe PWN. Warszawa. s. 19, (2002).

- Mirski A., Innowacyjność a zarządzanie zrównoważonym rozwojem przedsiębiorstwa, s. 146-150, Pobrano z: [http://www.ptzp.org.pl/files/konferencje/kzz/artyk\\_pdf\\_2014/T1/t1\\_140.pdf](http://www.ptzp.org.pl/files/konferencje/kzz/artyk_pdf_2014/T1/t1_140.pdf), (2014).
- Mom, T.J.M., Van Den Bosch, F.A.J., Volberda, H.W., Investigating Managers' Exploration and Exploitation Activities: The Influence of Top-Down, Bottom-Up, and Horizontal Knowledge Inflows, *Journal of Management Studies*, vol. 44, iss. 6, pp. 910-931, (2007).
- Noga A., Ptak A., Impact of the human factor on the evaluation of the production process, *Wydawnictwo Wydziału Zarządzania Politechniki Częstochowskiej, Częstochowa*. s. 467-474, (2018).
- Olejniak R., Stability and quality map of Toyota technological processes and its computer-aided marketing analysis. *Polish Journal of Management Studies*, Vol. 12, No 2, pp. 122-129, (2015).
- Ostasiewicz S., Rusnak Z., Siedlecka U., *Statystyka. Elementy teorii i zadania*, Wydawnictwo Akademii Ekonomicznej im. Oskara Langego we Wrocławiu, Wrocław, (2001).
- Schonberger, R.J., Japanese production management: An evolution-With mixed success. *Journal of Operations Management*, vol. 25, iss. 2, pp. 403-419, (2007).
- Schwarz, U. Nielsen, K.M. Stenfors-Hayes, T.; et al, Using kaizen to improve employee well-being: Results from two organizational intervention studies, *Human Relations*, Vol. 70, Issue: 8, pp. 966-993, (2017).
- Wojnicka-Sycz E., Sycz P., Public Innovation Policy and Other Determinants of Innovativeness in Poland, *The Innovation Journal: The Public Sector Innovation Journal*, Volume 21 (3) (2016).

# Information and Customer Purchase Decisions on Dynamic Markets

Tomasz Lis \*

*Faculty of Management, Czestochowa University of Technology, ul. Armii Krajowej 19b, Czestochowa 42-200, Poland*

---

## Abstract

The functioning of a man has always been connected with information. This is the basic factor determining its activity. It applies to man's personal and professional life. Of course, it also applies to structures co-created by man, that is companies. Before making a decision, the client analyzes the information already available and acquires new ones from any source to which he has access. In this respect, today man has great, practically unlimited possibilities. In such a reality, according to the author, it is particularly important for companies to conduct active activities in the information world - in the paper called the information space. Conscious delivering, controlling, supervising the spread, correcting, identifying - information, but also identifying and establishing cooperation with entities having the power of influence in the information space is, according to the author, a key factor of success in the dynamic market. In the paper, results of research carried out on a group of over 300 students of the Faculty of Management at the Czestochowa University of Technology: employed and unemployed, are presented. Due to the active participation in the information space, the use of information to make purchases, and at the same time sales, as well as acquisition of knowledge in order to manage enterprises, it is a good research group. The aim of the paper is to identify the meaning of information in human life, especially in the context of purchasing decisions. The aim is also to identify the features, advantages and requirements of active functioning in the information space.

*Keywords:* Information, information systems, decisions, dynamic markets

---

## 1. Introduction

As states W. Krztoń information has always played a very important role in human life, however, in relation to enterprises functioning, it gained a special meaning when it was credited as resources in the 1970s. At the same time, as the author emphasizes, information has become a commodity that, like those with a material form, can be bought and sold. (Krztoń, 2015)

Information is the basis of the decision. The concept of decision itself is defined as "a conscious, non-random choice of one of many (at least two) possible ways of acting" (Bolesta-Kukulka, 2000). Decisions are related to a situation in which there are many, more than one possible events. Which event will happen depends directly on the actions taken, which are always the result of the decision.

Decisions affect everything that is associated with the functioning of all market participants. Their basis is awareness and knowledge of: the situation, circumstances, realities, future, the object related to the choice of event that will be realized. Awareness and knowledge are, in a way, an image of reality composed of information that reaches the individual and, most importantly, it is understandable and legible to it. (Lis et al., 2016)

The most important activities undertaken by the company one should include those intended to affect the operation of those market participants who may become their customers (Shankar and Smith, 2003).

Understanding of customer behavior allows to adjust the company's operations to their needs and expectations. It thereby contributes to competitive advantage (Liczmańska, 2015). Customers making purchasing decisions base on information already possessed, as well as those to which they can access.

---

\* Corresponding author. Tel.: +48 343 250 378  
E-mail address: Tomasz.lis@wz.pcz.pl

The activities of enterprises aspiring to gain the competitive advantage should be associated on the one hand with identifying, acquiring and using information, and on the other hand providing them. The key is to understand customers, their needs and expectations, to match the offer and to realize their own existence and competitive advantages.

## **2. Information in the decision-making process**

As A. Holska states, "the decision-making process includes a logically connected group of thinking operations, in the right order, allowing assessment of the decision situation and selection of the most favorable option" (Holska, 2016). In this definition, there is no reference to information. However, in reality, each stage of the process is closely related to information, operations performed on them and using them.

Thinking operations are nothing but actions carried out in human mind on the information available to the individual at a given moment, using his knowledge and experience. The ordering of operations is also related to the available information, knowledge and experience. It should also be mentioned here, that knowledge and experience affecting the course and effects of the decision-making process are the result and also depend on information obtained during everyday normal functioning. (Lipczyński, 2014)

The key element of the cited definition of the decision-making process is the assessment of the situation and selection of the most favorable variant. Any limitation in the access to information, lack of possibilities and the ability to connect them negatively affect the analysis of the situation. This in turn influences the choice of event to be realized. Decisions are, therefore, the result of information that is visible to the individual, understandable and which are acquired and "absorbed" by it.

The described principle is used by enterprises (in order to try to influence customer behavior). Through promotions, price reductions, advertisements and suppliers one tries to convince them to take advantage of their offer. However, these activities are the source of only a small group of information used in purchasing decisions. Their participation in the author's opinion decreases with the development of IT and with increasing the general amount of information that becomes available (Tomaszewska, 2013) to contemporary recipient. This is despite the possibility of activating these activities, and thus increasing the amount of information consciously transmitted by enterprises.

According to the author, the information obtained by entities with direct experience in cooperation with the supplier or the use of certain goods gains in importance. The importance of information about the company and its offer is also given by entities, which, as a result of specific events and situations, acquired them, and which do not belong to the group previously indicated: employees, observers, people who obtained information as a result of hearing it.

Every action taken by and inside an enterprise is the source of information. It is not only a conscious action aimed at providing information to the environment. Increasingly, the client, as the person aware of the desirability of business operations (Pomffyova et al, 2017), which at the same time does not always translate into their honesty, is looking for independent information. By using information technology, especially from the Internet (Bucko et al, 2017), it has the ability to identify and obtain information about the company and its offer from a very large number of sources. At the same time, these sources are independent and often unrelated to each other, which increases their reliability and the value of generated information (Szpunar, 2011).

Every action (conscious and unconscious) is a source of information sent to the environment and thus to potential clients. Information is the basic factor in the decision-making process, including purchasing decisions. Thus, any negative information generated in and by the company has a negative impact on customers' purchasing decisions. Similarly, with any negative information generated by any market participant, which is beyond the awareness, control and operation of the company. (Lis et al., 2017)

According to the author of this publication, achieving success now requires the full awareness of the information generated. It is necessary to eliminate the possibility of negative information. Additionally, it is necessary to identify information about the company and its offer, in order to strengthen them, activate spreading, correct, explain and deny (untrue information).

This necessity results from the dynamism of contemporary reality, in which speed, volatility and uncertainty are the most important features of the market. Any information that is beyond the control and influence of the company has an unpredictable effect on the purchasing decisions of customers. It can thus limit the effectiveness of deliberate actions, hinder achievement of goals and negatively affect the competitive position.

## **3. Consumer behavior in a dynamic market**

Characterizing the behavior of contemporary clients, one can use the features describing the dynamic environment of the functioning of enterprises. M. Matejun, M. Nowicki to these characteristics include: structure, complexity, variability, uncertainty, potential occurrence of opportunities and threats, multifaceted, space, time, conditional context. (Matejun and Nowicki, 2013)

Understanding current and future customer behavior is one of the most important goals of enterprises. Customer behavior can be defined as "all activities and perception of the consumer, comprising the preparation of decisions on product selection, making and consuming of that choice. (...) activities related to search, purchase, use and assessment of goods and services that have the ability to meet the needs" (Dąbrowska and Janoś-Kresło, 2014). On the basis of the

definitions provided, it can be concluded that customer behavior is based on decisions in which information plays a key role. In this respect, one can identify decision about: need (willingness, necessity), choosing the object of the need (eg choosing a product from the group of products with the same or similar features), choosing the supplier.

The decision about the existence of a need may be caused by information generated in the immediate vicinity of the unit, but also by those obtained from its external environment. The first group is information, which sources are, for example, objects (damage, destruction, expiration, limitation of the level of functionality resulting from technological development - it can be described as "dead"), but also people from close relatives (family, friends). The second group includes information from people around, the media and, in general, all sources from which an individual can obtain information. The choice of the subject of the need and the supplier are information from every possible source that, in the opinion of the entity, has and/or can dispose.

The presented model of customer behavior is current, regardless of the conditions in which the unit operates. It can, however, proceed in a static or dynamic way. What determines the increase or decrease of the degree of dynamism is the amount of information provided to the unit. Technological development, especially development in the field of ICT, gives the possibility of access to virtually unlimited amount of information, it also allows the flow of information in real time without time or place restrictions. (Łodziana-Grabowska, 2016) All this makes customer behavior in a dynamic reality more and more dynamic. They are variable and difficult to predict.

#### 4. Information and customer behavior – research results

The article uses the results of a survey conducted on a group of 357 full-time and part-time students, 1st and 2nd degree of the Faculty of Management at the Częstochowa University of Technology. The questionnaires were completed by working people - 40.34% of respondents and unemployed. The aim of the study was to identify the meaning of information in the human life, both in professional and private life - the client.

One of the most important activities of enterprises focused on encouraging to start and continue cooperation, and thus on influencing customer behavior, is shaping an appropriate policy in the field of customer service. Because customers are the beneficiaries of these activities, it seems necessary to adjust the service process to their expectations and requirements. From of the persons participating in the survey who declared the fact of employment, 86.11% declared taking into account the requirements and expectations of customers in their enterprise. According to 5.56% of surveyed, this is not done, and 8.33% does not know anything about it (Fig. 1).

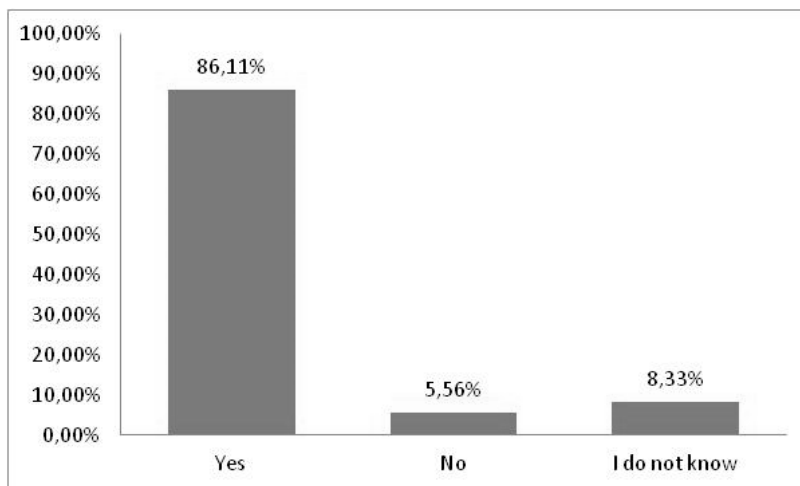


Fig. 1. Taking into account the needs, expectations and requirements of clients when developing the offer and / or customer service standards

Source: Own study

Adapting to the dynamically changing market conditions related to the use of opportunities and avoiding threats, requires not only listening and taking into account customer feedback. It is also necessary to monitor the actions taken by competitors and other entities whose activities may have an impact on the functioning of the company and its competitive position. Market monitoring and taking account information obtained this way in management was confirmed by 64.58% of the surveyed employees. According to 14.58% of them, such activities are not undertaken in enterprises that employ them. In turn, 20.83% does not know whether these activities take place or not (Fig. 2).

On the basis of the presented distribution of answers to 2 questions, it should be stated that as far as enterprises are aware of the need to monitor and take into account the needs and expectations of clients, they seem to downplay the issue of obtaining information related to competition activities and other entities affecting them. It is so strange that this information allows to gain knowledge about upcoming events, as well as consolidate knowledge about clients. While monitoring the behavior of customers, one cannot ignore the behavior of other market participants.

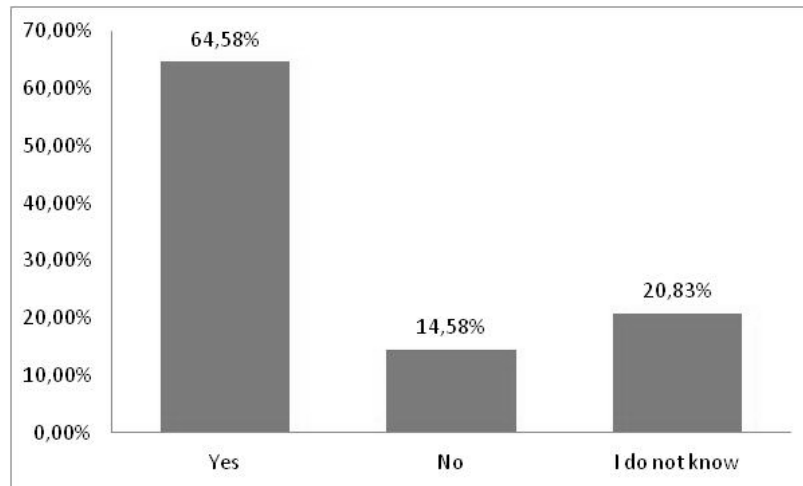


Fig. 2. Acquiring and taking into account in the management information about competition activities and market events in the environment

Source: Own study

Virtually all market participants, whose activities may have an impact on the functioning of the company and their competitive position, have information and knowledge that can be used to improve the company. Therefore, taking into account the dynamism on the market, it seems necessary to constantly monitor the market in order to identify and establish cooperation with entities that are or might be interested in establishing cooperation. This cooperation is to be connected with the acquisition/exchange of information and knowledge aimed at improving management (Goliński et al, 2016) and offer. The fact of conducting such cooperation in relation to the improvement of the offer is confirmed by 63.89% of respondents, and the improvement of management is confirmed only by 38.19% of the surveyed employees. There is no such cooperation in relation to the improvement of the offer according to 21.53% of surveyed, and the improvement of management 33.33% of respondents (Fig. 3). The obtained results are puzzling, because companies seem to listen to opinions about the course of the customer service process, while still a low percentage (and 63.89% should be considered as such should take into account the dynamism of the market) takes into account information and knowledge of clients and other market participants while shaping the offer. It is even worse in the case of improving management. It should be clearly emphasized that in the author's opinion attempts to influence customers behavior, including decisions (Gawas et al, 2018) made by them, have to be connected with providing positive information about the company and its offer to customers. And there seems to be no better way than to make every action aware that the client is really important and his needs are taken into account. At that time, he is more willing to provide strategically important information to make purchases (Mazursky, 2000), but also to provide positive information about the company to other (potential customers) entities, encouraging them to cooperate - on every level (Shamim et al., 2014).

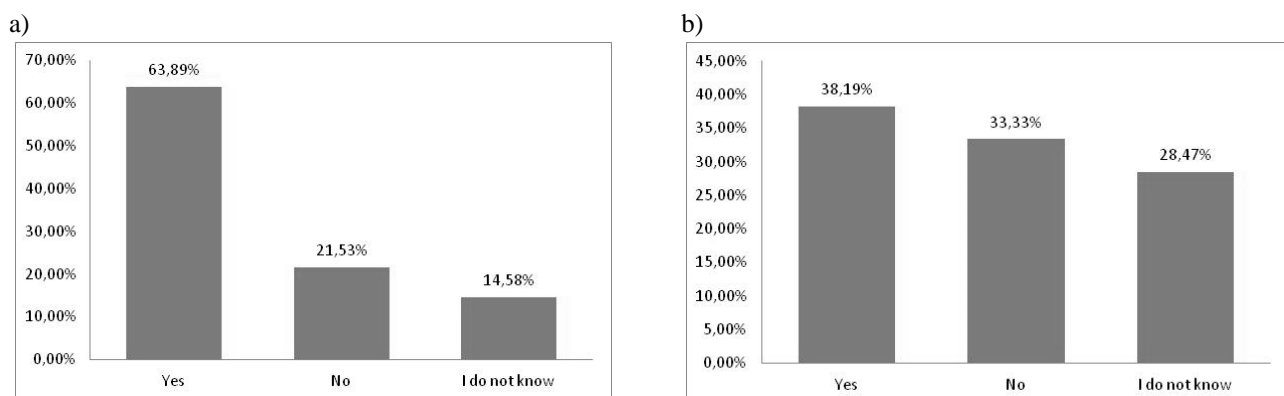


Fig. 3. Cooperation with the environment in the scope of a) improvement of offers b) business management

Source: Own study

Respondents asked about whether information gathered in the company, regarding the clients' needs, expectations and requirements affect its ability to take actions aimed at customer satisfaction with cooperation, thus influencing its decisions and behavior, stated that: it does not matter - 2.80%, it has a small meaning - 10.36%, significant - 81.51%, no opinion - 5.32% (Fig. 4). This confirms the awareness of the importance of information from the customer in shaping his contentment, and thus his behavior.

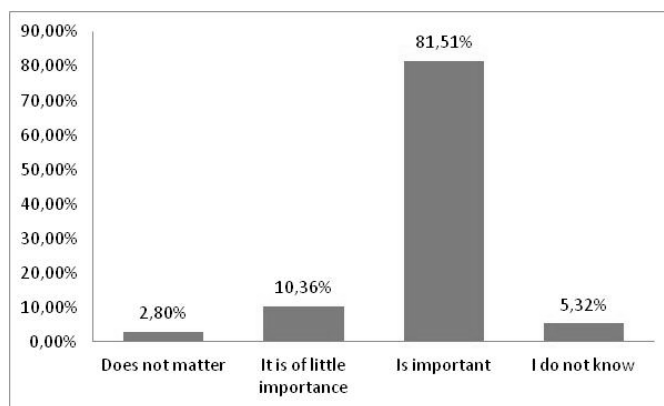


Fig. 4. Gathering information about the needs, expectations and requirements of customers, and the ability of enterprises to take actions related to customer satisfaction

Source: Own study

The importance of information in purchasing decisions of clients can also be illustrated by analyzing the impact of negative information obtained from various available sources. Only 4.20% of the responders said they did not affect their purchasing decisions. 20.17% of respondents said that they have an impact, but they pay more attention to the price or close location of the supplier. The majority of respondents believe that negative information has the big impact on decisions. 16.53% said their impact was decisive. No opinion was voiced by 4.20% of respondents. The distribution of responses confirms very important role of information reaching the customer - in the context of purchasing decisions.

## Conclusion

Customer behavior is of interest to every company. The competitive position depends on them. Analyzes and research are carried out. However, the problem in this respect is the large volatility, uncertainty and dynamism of contemporary markets, including customers. It is highly probable, that the results of analyzes while recognizing in decisions taken to meet customer expectations and requirements, are no longer valid. Enterprises try to study behavior, including customer requirements, in a predictive way. Considering the significant pace of changes, these forecasts are always subject of high risk.

As the results of the research presented in the article showed, the clients take into account information about the object of their interest and suppliers having their offer in making their purchase decisions (Bajdor et al, 2016). In connection with the above, every effort should be made to provide the existing positive and potential positive information to customers. One should also try to eliminate, correct and explain misunderstandings, doubts and negative and untrue information. At the same time, one should try to cooperate on the base of information with all possible market participants who have or can have important information for the company. All of them allow to understand current, but more importantly, future customer behavior.

## References

- Gawas A., Niyati Kulkarni P., Mehendale S., The Role of Social Media Marketing In Customer Purchase Intent – A Methodological and Thematic Review, *Asian Journal of Management*, 9(1), pp. 761-766, (2018)
- Bajdor P., Lis T., Ptak A., *The Role of Information/Knowledge Flow in the Clients' Purchasing Decisions*, *International Institute of Social and Economic Sciences (IIES)*, 3rd Business & Management Conference, Lizbona, Portugalia (22 do 25 marca 2016 r.), pp. 22-32, (2016)
- Bolesta-Kukulka K., *Decyzje menedżerskie w teorii i praktyce zarządzania*, Wydawnictwo Naukowe Wydziału Zarządzania Uniwersytetu Warszawskiego, Warszawa, p. 110, (2000)
- Bucko J., Kakalejcik L., Ferencova M., Safarik P.J., The Internet and its Use in Pre-Purchase Stage in Europe and Asia- Management of Marketing Efforts, *Polish Journal of Management Studies*, (2017); 15 (2): 16-26
- Dąbrowska A., Janoś-Kresło M., *Zachowania zakupowe polaków w świetle badań własnych*, *Zeszyty Naukowe Uniwersytetu Szczecińskiego, Problemy Zarządzania, Finansów i Marketingu*, no 36, pp. 9-21, (2014)
- Goliński M., Włodarczyk Z., Miądowicz M., IT Solutions Supporting the Management of Information of Employees ' Competencies, *Polish Journal of Management Studies*, 13 (2), pp. 46-57, (2016)
- Holska A., *Teorie podejmowania decyzji*, [w] *Zarządzanie, organizacje i organizowanie – przegląd perspektyw teoretycznych*, pod red. K. Klincewicz, Wydawnictwo Naukowe Wydziału Zarządzania Uniwersytetu Warszawskiego, Warszawa (2016)
- Krztoń W., XXI wiek – wiekiem społeczeństwa informacyjnego, *Modern Management Review*, vol. XX, 22, 3, pp. 101-102, (2015)

- Liczmańska K., *Kluczowe czynniki determinujące zachowania konsumenckie na przykładzie mieszkańców województwa kujawsko-pomorskiego*, Zeszyty Naukowe Uniwersytetu Szczecińskiego, Problemy Zarządzania, Finansów i Markietingu nr 41, t. 2, Szczecin, pp. 107-108, (2015)
- Lipczyński T., Wiedza jako narzędzie budowy przewagi konkurencyjnej małych i średnich przedsiębiorstw, *Informatyka Ekonomiczna*, 1(31), p 48, (2014)
- Lis T., Bajdor P., Ptak A., Budzik-Nowodzińska I., *Information Management in the Company's Information Space*, The International Academic Forum (IAFOR), The Asian Conference on Sustainability, Energy & the Environment 2016, Kobe, Japonia (09 do 12 czerwca 2016 r.), pp. 351-361, (2016)
- Lis T., Bajdor P., Ptak A., *Zarządzanie w przestrzeni informacyjnej a efektywność zarządzania wiedzą w przedsiębiorstwie*, *Wiedza menedżerska i technologie informacyjne w biznesie* (red.) PERECHUDA Kazimierz, CHOMIAK-ORSA Iwona, Wydawnictwo Wydziału Zarządzania Politechniki Częstochowskiej, pp. 25-34, (2017)
- Łodziańska-Grabowska J., Badania wpływu Internetu na decyzje zakupowe konsumentów, *Marketing i Rynek*, no 3, pp. 30-34, (2016)
- Matejun M., Nowicki M., *Organizacja w otoczeniu – od analizy otoczenia do dynamicznej lokalizacji*, [w] *Nauka o organizacji. Ujęcie dynamiczne*, pod red. A. Adamik, Oficyna a Wolters Kluwer Business, Warszawa, pp. 153-154, (2013)
- Mazursky D., The effects of time delays on consumers' use of different criteria for product purchase decisions, *Journal of Business and Psychology*, Volume 15, Issue 1, pp. 163–175, (2000)
- Pomffyova M., Kozarova M., Krajcik V., Innovative and Information Perspectives of Business Management, *Polish Journal of Management Studies*, 16 (2): pp. 221-232, (2017)
- Shamim A., Balakrishnan V., Tahir M., Shiraz M., Critical Product Features' Identification Using an Opinion Analyzer, *The Scientific World Journal*, Volume 2014, pp. 1-9, (2014)
- Shankar V., Smith A. K., Rangaswamy A., Customer satisfaction and loyalty in online and offline environments, *International Journal of Research in Marketing*, vol. 20, no. 2, pp. 153–175, (2003)
- Szpunar M., Internet – nowe modele komunikacyjne czy powielanie schematów właściwych mediom masowym?, *Media, Kultura, Społeczeństwo*, nr 1 (6), pp. 5-7, (2011)
- Tomaszewska A.W., Dostęp do technologii Informacyjno-komunikacyjnych w społeczeństwie informacyjnym. Przykład polskich regionów, *Acta Universitatis Lodziensis, Folia Economica* 290, pp. 23-25, (2013)



# The Online Consumers' Recommendations

Elżbieta Karaś<sup>a\*</sup>

<sup>a</sup>*Opole University of Technology, Faculty of Economics and Management, Luboszycka 7, 45-036 Opole, Poland*

---

## Abstract

The development of the Internet and social media influenced the change of the business and communication environment on the market. Enterprises are more frequently doing online marketing activities. They use new ways and communication tools, acquiring knowledge and experience, and even the skills of their consumers. Currently, consumers on the Internet actively spread their opinions about enterprises and products. They exert an increasing and real influence on the functioning of enterprises, they are co-creators of the new business space in the virtual world - prosumers. The Internet provides them with free communication and dissemination of a huge amount of information about companies, brands, as well as opinions and recommendations about purchased products or services. In this way, consumers generate knowledge and increasingly transform the business market, the way of transactional relations and the implementation of social expectations. The specificity of this phenomenon influenced operations of many companies, which currently use recommendation marketing to implement specific strategic goals. Under these conditions, the business environment for enterprises becomes a completely new, difficult to predict and control area of operation. The development of a new strategy based on consumer recommendations may be an opportunity for them to build a positive image, reputation and further development of the company.

The aim of the article is to present the specifics of recommendation marketing and to identify changes in consumer behavior in the context of creating and perceiving marketing content in the Internet environment. General premises of the use of internet recommendations, threats and instruments of recommendation marketing used by Polish enterprises have also been indicated.

*Keywords:* consumer; marketing; recommendation marketing

---

## 1. The definition of recommendation marketing

In the modern world, traditional forms of marketing communication no longer show adequate effectiveness in the face of new technological and social phenomena. Enterprises are searching for alternative forms of communication with the market. The development of the Internet and changes in information technology have revolutionized mutual relations and communication. The Internet allows companies to freely communicate informally and quickly exchange the information they need on the web. An important element in this process is the presence and activity of consumers. As Internet users they communicate with each other, share their content and opinions about products. It is a new form of informal communication that can be effectively used in word-of-mouth marketing (WoMM). WoMM marketing is an activity aimed at triggering the recommendation of a product, brand or service to potential clients. The recommendation can spread in any environment, and the Internet seems to be the perfect place. This is mainly favored by the nature and specificity of communication on the web and the evolution that the modern consumer has undergone, transforming into an active and conscious prosumer. He has a huge resource of useful knowledge and information. His knowledge is available and very useful for the implementation of enterprises in a demanding and rapidly changing market. Prosumerism is generally defined as "the concept of customer participation (usually the consumer) in creating an enterprise offer by actively promoting it, mainly through modern forms of communication" [Niedzielska 2016, p. 350].

Contemporary prosumers co-create content, products and services, shape consumer opinions and images of companies, brands and products, actively seek information, share their consumer knowledge. Advertising information from the manufacturer or service provider in the traditional way is insufficient. The unilateral message has been replaced by interactive communication, and consumer choices are influenced by opinions and recommendations of others available online on the web. For modern prosumers, these are much more valuable and more reliable sources of

---

\* Elżbieta Karaś. Tel.: +48 512 260 615  
E-mail address: e.karas@po.opole.pl

knowledge than information coming directly from producers or from advertising. The recommendation is defined as a direct and verbal way of communication between two or more people, which contains positive, negative or neutral information about the company or its offer. Its non-commercial nature is emphasized. This means that the person providing the recommendation does not receive material benefits from their transfer [Tewes 2003, p. 100]. A distinction should also be made between active and passive recommendations. Active recommendations rely on intentional and conscious transfer of information, while passive on unconscious impact on other buyers [Wille 2005, p. 153].

As the results of consumer surveys show, the most important factor affecting the customer's recommendation potential is his commitment to purchase. Very often, consumer engagement is considered as a basic category describing consumer behavior after purchase. Product and situational engagement can be distinguished. The first one is based on long-term, internal, not related to a specific purchase situation, the consumer's interest in a given product category. It results in an intensive search for information by the customer, thus acquiring knowledge about the product. As a consequence, it strongly determines its future recommendations in the long-term. On the other hand, situational engagement is short-lived and occurs just before and immediately after the purchase. Its influence on the recommendations may be very strong, but short-lived [Wagenheim 2003, pp. 90-92].

## **2. Reasons for applying recommendation marketing**

The basic factor conducive to the use of recommendation marketing is primarily the development of social media and relationships in the Internet network along with the resources of knowledge that have become the main source for obtaining marketing information. Other factors are: less effective impact on consumers of traditional marketing instruments and a change in consumer behavior on the Internet. These factors will be briefly presented.

New business environment conditions set different approaches to marketing issues. Changes in marketing result from the fact that in recent years the roles and expectations of consumers have changed, they have become co-creators of the electronic space, they often form huge network groups that communicate through social media. At present, it is believed that efficient communication of enterprises with their clients using social media is the basis for shaping the right relations between the company and the environment. A. Kaplan and M. Haenlein define social media as a "group based on web-based application solutions that rely on the ideological and technological basis of Web 2.0 and which enable the creation and exchange of user-generated content" [Kaplan, Haenlein 2010, p. 59]. The essence of these media is the creation of such content that is readily reproduced on other websites, blogs and is generally easily spread on the Internet. They are completely independent of the company and have the greatest impact on the reputation and image of the company. Social media are today the strongest and most influential medium of communication, because they have all the features necessary for effective online information exchange: simplicity, honesty, trust in the sender, openness, impartiality, etc. Positive opinions and comments in the media are the most valuable for smaller ones companies that can promote their products and compete with well-known brands.

The development of the Internet and social media has also contributed to the creation of new marketing promotion techniques. They provide interesting opportunities from the point of view of the company to reach the larger group of customers, employees or representatives of public opinion. These include: viral advertising, WoMM marketing, web marketing (SEO), Web 2.0 marketing, e-mail marketing, e-branding and e-CRM [Budzyński 2008, pp. 184-189]. All mentioned promotion techniques can be used on the Internet and widely used in creating and monitoring the image of a company, brand or specific product. In this way, enterprises gain opportunities to build new business models, strategic and marketing activities in the virtual and real space.

Other elements favoring the use of recommendation marketing are related to changes in consumer behavior and expectations on the Internet. The process of making purchase decisions differs radically from traditional behaviors and consumer decisions. In general, there were two types of changes. The first change concerns the process of purchase decisions. The second change concerns the problem of trust in people grouped in social networks and the credibility of content passed between them.

Consumer's decision making process has been transformed. The traditional decision-making process is based on the consumer's gradual selection of potential offers, and after making the purchase, the relationship with the brand or company has not always been established. Such an approach to the decision-making process does not take into account the conditions that accompany modern consumers, that is, their active involvement in virtual social relations. The contemporary consumer behaves completely differently, makes purchase decisions very quickly and often follows the opinion of other users. Research on new media indicates a change in the consumer's decision-making process, followed by the stages of: consideration, purchase, evaluation and recommendation. The phases of consideration and purchase are much shorter, while the evaluation and recommendation phases are extended and strengthened. The consumer is suggested by the opinions and rankings of other members of social networks and is increasingly looking for information after making a purchase in order to confirm his decision. For example, the latest research from 2017 indicate that online opinions and recommendations affect purchase decisions among 90% of buyers [Hawlak 2017]. What's more, the indications from the respondents indicate that:

- 84% of people consider the opinion on the Internet to be reliable (it considers it as a personal recommendation).
- 54% of people visit company websites after reading positive reviews.
- 74% of people trust companies after reading positive reviews.

- 58% of people think that consumer ratings posted online are the most important source of information for them [Hawlk 2017].

Reports from research carried out in 2012 by Jupiter Research confirm the growing importance of recommendations on the Internet. According to the Jupiter Research report from this period: "77% of buyers read product reviews on various internet forums, and about 60% of respondents appreciate the opinions of other buyers from expert opinions and in their opinion the opinions of Internet users are the most valuable source of information" [Nielsen.com 2012]. In the last five years, therefore, the importance of consumer recommendations placed online has increased. The highest percentage of indications occurred in the group of consumers aged 22-29 [68%], in other age groups it gradually decreased to 42% of indications for buyers over 75 years of age [Rudawska 2012, p. 286]. These results show that the majority of Internet users increasingly base their purchase decisions on the product rating of the network. If the user does not find reviews about the brand and product on the web, he usually treats this as a lack of confidence and does not make a purchase. The lack of other people's assessments is a sufficient reason to look for another product, recommended by network users, with whom it combines a sense of belonging and trust resulting from it [Czarnecka 2012, pp. 170-178].

These facts suggest the necessity for the enterprise to change its marketing strategy, which should be focused on content creation and management in social media [Edelman 2011, pp. 99-102]. Effectively conducted communication in social networks brings a favorable assessment of the brand chosen by the consumer and positive opinions published on the web, which are extremely important for building consumer awareness and encouraging other users to buy. The new consumer decision-making method is also important due to the separation of the new phase - recommending, and thus building strong virtual relations on the Internet [Czarnecka 2012, pp. 170-178]. Social networks have strengthened the way network users interact. The mechanism of exerting influence, known from the real world, is intensified by almost instant access to opinions and rankings of others, because the network for many consumers is a favorite place for seeking recommendations [Nielsen.com 2012]. Due to high awareness of the needs, consumers more frequently provide feedback to enterprises, but above all to each other [Rudawska 2012, pp. 282-289]. Therefore, it becomes important to involve enterprises and consumers themselves in the virtual social relations.

The second aspect of considerations regarding consumer decision making concerns the problem of online trust. A novelty brought about by social networks is increased trust in people from the network, in contrary to people recognized socially as authorities. This is an important signal for companies that have so far promoted their products using the services of sports or pop culture stars. However, according to the rules of exerting influence, the people who we trust and recognize as familiar are more convincing. Network users feel safe in the group of people who have invited them to their circle of friends or whom their relatives know. Using the recommendations of people from a known and trusted social group is much more frequent among Internet users than referring to authorities or imitating celebrities [Czarnecka 2012, pp. 170-178]. These trends are also confirmed by the Global Web Index report, which reveals data on Internet users' activity in the network. It turns out that they primarily look for opportunities and promotional prices, make purchases, communicate with other Internet users and establish relationships. Consumers are also aware of their needs, know how to satisfy them and look for products that in the rankings of other users were the best [Global Web Index 2016].

### **3. Application of recommendation marketing in Poland**

The Americans are the world's precursors to recommendation marketing. In 2001, the world's first agency specialized in the activities of Word of Mouth - Tremor/VocalPoint was created by Procter & Gamble. In Poland and simultaneously in Europe, the first WoMM agency - Streetcom Polska was established in 2004 [Juszczak 2014, p. 74]. Since that period in Poland, there has been an increase in interest in modern marketing instruments adapted to the conditions of Internet space. Not without significance for the popularity of recommendation marketing is the fact that traditional forms of advertising and promotion are insufficient and inadequate to the needs of today's consumers.

As it was indicated in the article, recommendation marketing has a significant impact on consumer decisions, especially in the Internet, resulting in the activation of activities in this field, both from customers and enterprises on the Polish market. According to a survey carried out by the research firm Nielsen, in 2009, among over 25,000 people in 50 countries around the world, including Poland, 90% trust their friends' recommendations before making purchases [in section 2, similar data was presented; see also: Dwornik 2010, p. 6]. Generally, it can be stated that the published content about a brand or product, including reviews, play a very important role in the decision-making process, regardless of whether the purchase is made online or offline. Analyses show that depending on the type of product, up to 85% of internet users follow the initial stage of purchasing decisions, and 69% of customers are convinced of their credibility. The assessment of the credibility of the review increases with the age of the respondents, 67% of people aged 15-24, 70% of people aged 25-34 and 72% of people aged 35 and over consider them a reliable source of information [Andreask 2015, p. 69]. On the basis of the research, it was also shown that consumer recommendations placed in real and virtual space generate about 13% of sales [Zajac 2015, p. 78]. Recommendation marketing always reinforces the effect achieved through promotional activities undertaken by enterprises in commercial media by 15%. According to other data, the marketing of recommendations in real space increases sales five times than other paid advertisements in various types of media [Juszczak 2014, p. 74].

Recommendation marketing can take many different forms to be used in parallel, complementarily or in an integrated manner. In Poland, most enterprises combine traditional and new marketing tools. The most commonly used marketing instruments of recommendation are: shill marketing, internet amplifying (reinforcing), blogging and social media, product seeding campaigns with online participation of experts and opinion leaders, and e-commerce platform.

One of the classic forms of recommendation marketing is shill marketing. In this case, the information carrier should primarily be customers (brand ambassadors) who have good experience with the company and want to share them with others, usually in accordance with the rule of reciprocity, according to which a person would like to reciprocate with good advice to others, because beforehand someone did it's for him. An excellent indication of this type of activities are customer reviews posted on comparison websites and online stores, e.g. [ceneo.pl](http://ceneo.pl); [bonprix.pl](http://bonprix.pl). Before purchasing a specific product, you can read the opinions of people who have previously purchased it and its averaged rating on a scale from 1 to 5. This is extremely helpful, because it allows you to obtain objective (both positive and negative) information, including on the quality of clothing, size, fabric condition after washing, etc.

An example of activities in the field of recommendation marketing using the opinions of brand ambassadors was the Morning Fresh dishwashing fluid produced by PZ Cussons Polska SA campaign organized at the end of 2014 by the company Streetcom. The aim of the campaign was to increase brand awareness, inform about the qualities of the product, and gathering brand recommendations. The action was attended by 300 ambassadors who received a package with two of the four liquid variants available on the market and information materials about them. The ambassadors' task was first test the products and then recommend them friends and posting opinions on social media. The main emphasis, however, was on online activity. During the five weeks of the campaign its overall reach in virtual and real space amounted to over 1.5 million people, with an initial assumption of 400,000, and the recommended product gained a significant advantage over other brands - both among ambassadors and their friends [Zajac 2015, p. 79].

Another form of recommendation marketing is internet amplifying, which mainly involves communication with consumers on forums websites, but also placing reviews on sharing sites (e.g. YouTube, Slideshare) or social networks. The Internet amplifying most often takes the form of e-Spokesman for the brand and online Expert. e-Spokesman of the brand is its official representative who speaks in a discussion expressing the official position of the organization and answering questions. The e-Spokesman's function is completely public, which ensures credibility of the message and distinguishes suspicion about dishonest practices in the field of marketing carried out by alleged clients, and in fact employees of the enterprise [Ratuszniak 2010, p. 22]. Online Expert is a form of the e-Spokesman of the brand, supported by constant network monitoring. The main task of the online Expert is to manage the brand's reputation on the web, which is an important element of SERM (Search Engine Reputation Management), through impact on the positioning of positive and neutral threads in the search engine, as well as locating threats and preventing the development of crisis situations [Niedzielska 2016, p. 348].

An ideal environment for the development of recommendation marketing is the blogosphere. Blogs are understood as a systematic, chronological publication of own opinions and beliefs for non-commercial purposes by Internet users [Bednarska 2015, p. 14]. A modern blog is a website characterized by frequent entries, with a personal, informal style that can be commented on by Internet users. Not all blogs are, however, suitable for a recommendation platform, and not every blogger can be an effective amplifier. Blog must be very popular and credible, its author - honest and trustworthy. Recommendations on blogs, in addition to many positive elements, such as the use of the opinion of a recognized person for the authority in specific circles or the opportunity to reach a broad but targeted group, they also have a negative aspect. Very unethical action in this area may be running so-called flogs, or false blogs presenting products specified brands in the most favorable light. Such activities led, among others Sony or Wal-Mart. These blogs, after the discovery of fraud by Internet users, have been ceased.

Other recommendation marketing tools are product seeding campaigns, as well as the activity of trendsetters and opinion leaders. Product seeding consists in providing campaign participants, usually opinion leaders, with a full-fledged product for testing, and in the next stage on stimulating testers for recommendations. In many seeding campaigns, opinion leaders receive not only products, but also their samples, which facilitates their recommendation when distributing the tested product among friends and increases the reach of the seeding campaign. In Poland, many enterprises use this method of running a campaign, locating their productive various forums, and above all in social media. In Poland, there is a clear trend of growth in the number of social media users and communicators through phones, in the last year it was a 20% increase in population. The most popular social media are YouTube and Facebook, Poles use it much more willingly than the average users in the world. Almost 60-64% of network users in Poland use at least once a day YouTube or Facebook, while on average in the world declared it to 45.7% respondents. According to the Gemius study, these websites are at the forefront of their category in Poland - over 22 million real users of Facebook on a monthly basis, and almost 20 million of YouTube. The ranking of the most common social media that is used, at least once daily, is following [Global Web Index 2016]:

- YouTube 64%
- Facebook 62%
- Google+ 33%
- Fb Messenger 32%
- Skype 25%
- Twitter 24%

In Poland, however, there is a low interest in using the WhatsApp communicator. According to the study, it is used by 38% of people globally, while in Poland only by 11%. The communication application taken over by Facebook has never gained much popularity in Poland, and Poles prefer to chat with FB Messenger [Global Web Index 2016].

There are other solutions on the Polish market based on recommendation marketing. Such an interesting solution that has big development perspectives are social commerce sites, which are a combination of e-commerce platforms with an active user community system. It is a solution based not only on consumer recommendations but, above all, using social relations and a communication system between Internet users built on them. Users of this type of services can optimize their purchasing decisions and reduce the associated risk using information provided by other users. The basic idea behind the creation of this type of services is the assumption that most purchase decisions are made under the recommendation of other people, and social commerce platforms are an ideal place where Internet users can exchange information about specific products, evaluate them, recommend and verify information provided by producers, and also follow the opinions of people who personally checked the product or used a specific service. However, social commerce services are fundamentally different from comparison websites or websites that publish consumer opinions. The idea of their creation is not impersonal and anonymous generation of reviews and opinions. Their functioning is based on social relations and mutual trust of users. The value and quality of the opinions posted there results mainly from the fact that users receive them from well-known and trusted people with whom they connect their real relationships. The most popular social commerce site in Poland is Allegro.pl auction platform, where consumers can post their recommendations and reviews online and make purchases. They also have the opportunity to meet in the real world, because Allegro.pl has been organizing meetings for its users since 2000 in order to increase loyalty, trust and willingness to cooperate between them [Karas 2016, p. 106].

#### 4. Conclusion

Recommendation marketing in Poland is developing intensively, there are more and more network users who are very active in the Internet space. There are indications that the growth tendency will continue. According to data from the Central Statistical Office, “about 82% of Poles use the Internet in 2016, and 3/4 of them declare to have an account on a social network” [Rajchel 2017, p. 128]. In this context, the prospects for the development of recommendation marketing, especially in social media, may prove to be a source of success for many enterprises. The use of appropriate marketing tools - activating consumers as carriers of recommendations - can be successfully used in social media. Their recipients are primarily young people, because in the case of people aged 15-24, the percentage of people using the network and portals reach almost 100%. In the future, they will be potential users of various products or services and will strongly influence the way of market transactions in the virtual world [Bednarska 2015, p. 27]. Recommendation marketing in social media currently adopts the most common form:

- running profiles and funpages,
- running applications, competitions and games, including on Facebook or Google+,
- launching video channels on YouTube and other platforms,
- monitoring and testing the condition of brands in the Internet,
- conducting campaigns on online forums [Niedzielska 2016, p. 350].

The analysis of the subject literature presented in the article and selected research results available in secondary sources confirm the significant impact of recommendation marketing on consumer purchasing decisions. Contemporary consumers are active people, they search the Internet space in order to gain knowledge and help in meeting their needs. They connect to various social groups, using modern technological and communication solutions. The prospects for the development of recommendation marketing are huge, especially in the Internet, which results in the continuous activation of activities in this field, both from customers and enterprises. Recommendation marketing can turn out to be a very effective form of action on the real or virtual market provided that they are ethical and reliable.

#### References

- Andreasik, A., Treści, którym ufają klienci, *Marketing w Praktyce*, No. 5, (2015).
- Bednarska, M., Obok nas w sieci, *Marketing w Praktyce*, No. 4, (2015).
- Budzyński, W., *Wizerunek równoległy*, Poltext, Warszawa, (2011).
- Czarnecka, A., Rola sieci społecznościowych w kształtowaniu tożsamości i zachowań konsumenta, *Handel Wewnętrzny*, May-June, Vol. II (2012).
- Dwornik, B., Szeptanie jest w cenie, *Raport: Marketing szeptany*, Interaktywnie.com, [interaktywnie.com/index/index/?file=raport\\_marketing\\_szeptany.pdf](http://interaktywnie.com/index/index/?file=raport_marketing_szeptany.pdf), [online], cit. 05.06.2018, (2010).
- Edelman, D. C., Budowanie marek w epoce cyfrowej, *Harvard Business Review Polska*, No. 12, pp. 170-178, (2012).
- Global Web Index, <http://greatdigital.pl/digital-poland-czyli-statystyk-dla-hr/>, [online], cit. 15.04.2018, (2016).
- Hawlk, K., *How to Encourage Customer Reviews (And Why You Should)*, <https://www.shopify.com/retail/how-to-encourage-customer-reviews-and-why-you-should>, [online], cit. 13.04.2018, (2018).

- Juszczyk, B., Siła opinii, *Marketing w Praktyce*, No. 10, (2014).
- Kaplan, A.M., Haenlein, M., Users of the world, unite! The challenges and opportunities of Social Media, *Business Horizons*, No. 53 (1), (2010).
- Karaś, E., *E-marketing przedsiębiorstwa w przestrzeni elektronicznej*, [in:] Wielki, J. (ed.), Technologie informatyczne we współczesnej rzeczywistości gospodarczej, pp. 101-112, Oficyna Wyd. Politechniki Opolskiej, Opole, (2017).
- Niedzielska, A., Narzędzia marketingu rekomendacji w ujęciu teoretycznym i praktycznym, *Handel wewnętrzny*, No. 2, pp. 345-354, (2016).
- Nielsen.com, [http://www.nielsen.com/us/en/insights/reports/\(2012\)/state-of-the-media-the-social-media-report-2012.html](http://www.nielsen.com/us/en/insights/reports/(2012)/state-of-the-media-the-social-media-report-2012.html), [online], cit. 15.04.2018, (2012).
- Ratuszniak, B., Gdzie szeptać? Narzędzia WoMM pod lupą, Raport: Marketing szeptany, [interaktywnie.com/index/index/?file=raport\\_marketing\\_szeptany.pdf](http://interaktywnie.com/index/index/?file=raport_marketing_szeptany.pdf), [online], cit. 15.04.2018, (2010).
- Rudawska, E., Niezadowolony klient w sieci, *Handel Wewnętrzny*, May-June, Vol. II, pp. 281-289, (2012).
- Rajchel, D., *Gospodarstwa domowe w dobie rozwoju usług elektronicznych*, [in:] Wielki, J. (ed.), Technologie informatyczne we współczesnej rzeczywistości gospodarczej, pp. 123-136, Oficyna Wydawnicza Politechniki Opolskiej, Opole, (2017).
- Tewes, M., *Der Kundenwert im Marketing*, Deutscher Universitätsverlag, Wiesbaden, (2003).
- Tkaczyk, J., *Blaski i cienie wykorzystania serwisów społecznościowych przez przedsiębiorstwa*, [in:] Waśkowski, Z. (ed.), Komunikacja rynkowa. Kultura, perswazja, technologia, Zeszyty Naukowe Uniwersytetu Ekonomicznego w Poznaniu, No. 209, (2011).
- Wagenheim, F., *Weiterempfehlung und Kundenwert*, Deutscher Universitätsverlag, Wiesbaden, (2003).
- Wille, K., *Customer Equity*, Deutscher Universitätsverlag, Wiesbaden, (2005).
- Zajac, A., Streetcom/Morning Fresh. 300 ambasaderek zmywa naczynia, *Marketing w Praktyce*, No. 4, (2015).

## Building Organizational Innovation through Strategic Orientation: A Lesson from Cement Industry in Indonesia

Muafi<sup>a</sup>, Joanna Tabor<sup>b\*</sup>, Benny Wendry<sup>c</sup>, Jun Surjanti<sup>d</sup>, Rizqi Adhyka Kusumawati<sup>e</sup>

<sup>a</sup>Management Department, Economic Faculty, Universitas Islam Indonesia

<sup>b</sup>The Management Faculty, Czestochowa University of Technology

<sup>c</sup>Business Administration Faculty, Doctoral Program, Universitas Brawijaya Malang

<sup>d</sup>Management Department, Economic and Business Faculty, Universitas Negeri Surabaya

<sup>e</sup>Finance and Banking Department, Economic Faculty, Universitas Islam Indonesia

---

### Abstract

The manufacturing industry is becoming one of the industries that are included in the agenda of the President of Republic Indonesia to have readiness to face industry 4.0. This research uses purposively selected samples of managers at 3 largest cement companies in Indonesia. The growing number of foreign cement industry in Indonesia make the domestic cement companies should have a strategic orientation (resource, market, entrepreneurship, and learning) in order to be able to increase the organizational innovation and organizational performance in the middle of a very high environmental uncertainty. Respondents were taken with proportional area random sampling techniques based on managers' perception. The statistical technique is using Partial Least Square to test the hypothesis. The result concludes that environmental uncertainty has a great impact on the increase of strategic orientation (resource, market, entrepreneurship, and learning). Strategic orientation is required for companies to improve organizational innovation in facing the industry 4.0 that require a very high level of difficulty

*Keywords: Environmental Uncertainty; Strategic Orientation (resource, market, entrepreneurship, learning); Organizational Innovation*

---

### 1. Introduction

Currently, the Indonesian government is committed to improve the industry's competitiveness and independence through the industry 4.0, including cement industry as manufacturing industry in Indonesia. It is known that the strategic orientation of a company depends on what the company wants to achieve. Cement industry is faced with the condition of a very turbulent environmental uncertainty. The level of cement industry competition in Indonesia is increasingly competitive. Several foreign cement companies have been permitted to operate in Indonesia, such as Lafarge–Holcim, Conch, China National Building Material, and Heidelberg-Indocement. They are competing to reap a huge market share in Indonesia. This makes some domestic cement companies overwhelmed to compete. The growth of production capacity above the increase of national cement consumption is the main cause of the high competition of the national cement industry for a long term. It is estimated that the national cement industry will experience an oversupply of 43 million tons in 2018 compared to 2017. The continuation of cement industry competition will make the producers difficult to raise the selling price. Some research has proved that environmental uncertainty can have an influence toward strategic orientation directly or indirectly (Muafi, 2009a; Zahra et al., 1997; Covin and Slevin, 1989). Orientation strategy can also enhance organizational innovation (Obeidat, 2016; Szczepańska-Woszczyna, 2014). This research focuses on the three largest cement companies in Indonesia, because these companies have been known to have an increasing performance.

---

\* Corresponding author. Tel.: +48 60 946 0906; fax: +48 34 325 0244.  
E-mail address: joanna.tabor@wz.pcz.pl.

## 2. Literature Review

Some theoretical studies and findings of previous researches concluded that environmental uncertainty is the greatest challenge in managing business. Corporate executives are often confronted with the difficulty to control external environment due to limited costs, time, and information (Jones, 2007; Muafi, 2009a; Elbanna and Alhwarai, 2012; Sachpazidu-Wójcicka, 2017). Elbanna and Alhwarai (2012) have stated that sometimes managers are faced with decisions that are very irrational, unreasonable, and difficult to predict. This is because of the things as follows; (a) the gap due to causation of a relationship, (b) future events that are difficult to predict, (c) the resulting outcomes have uncertainties due to uncontrollable causes. The manager is faced with the inability to predict something accurately (Jonek-Kowalska, 2017). The capacity of information processing management becomes overloaded, so that it will have implications for the decision making that will be implemented (Robbins, 1994). The researcher identifies and summarizes from various literature sources that can be seen on Table 1.

Table 1. Indicators of Environmental Uncertainty Measurement

Indicator	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Complexity				*				*	*							*
Dynamism					*			*	*		*					*
Hostile	*	*		*		*	*		*	*	*	*		*	*	*
Volatility				*							*					
Heterogeneity											*					
Competition																
Complexity					*											
Munificence		*		*	*			*							*	
Benign		*			*								*			

Sources: (1) Dess and Beard (1984), (2) Covin and Slevin (1989), (3) Castrogiovanni (1991), (4) Shane and Kolvereid (1995), (5) Ward (1995), (6) Zahra et al. (1997), (7) Kean et al. (1998), (8) Luo (1999), (9) Lukas et al. (2001), (10) Li (2001), (11) Choe (2002), (12) Hodge et al. (2003), (13) Muafi (2009a), (14) Elbanna (2009), (15) Elbanna and Alhwarai (2012), (16) Carvalho et al. (2016).

Elbanna and Alhwarai (2012) have stated that company will have difficulty in achieving company outcomes when faced with hostile environment conditions. Muafi (2009a; Covin and Slevin, 1989) adds that environmental uncertainty is characterized by the setting of precarious industry, intense competition intensity, rigorous and competitive business climate, lack of exploitable opportunity, full of risks, pressure, and domination. On the other hand, if the company is faced with benign environment, then it is faced with a safe setting for business operation, has many investment and marketing opportunities, munificent, and easy to be manipulated. In relation with strategic orientation, hostile environment is more appropriate for entrepreneur strategic orientation, and benign environment is more appropriate for conservative strategic orientation. The research result from Luo (1999; Simerly and Li, 2000) concludes that there is no significant influence of munificent environment toward strategic orientation (innovation strategy, proactive, and high risk). In the contrary, complex and dynamic (hostile) environment have a significant effect on the innovative, proactive, and high risk strategic orientation.

Competitive strategy is identical to the term strategic orientation, which has been defined as “how an organization uses strategy to adapt and/or change aspects of its environment for a more favourable alignment” (Manu and Sriram, 1996). Hakala (2011) also defines strategic orientation as organization principles that drive and influence organization activity. Strategic orientation manifests the company culture and functions as the antecedent for organization practice and decision related to resource allocation and pursuit opportunities (Deshpande et al., 1993; Pilat, 2016). Different types of strategic orientations are not mutually exclusive (Gatignon and Xuereb, 1997). Resource orientation means that companies have to be able to mobilize its resources in a valuable and useful way. A unique, rare, and non-imitative resource will be a competitive advantage if the company can manage them strategically (Grant, 2002; David, 2001; Muafi, 2017). Several research findings have proven that when companies successfully implement market orientation, then they can produce superior innovation and a bigger success of new products (Deshpande and Webster., 1989; Kohli and Jaworski, 1990; Mahmud et al., 2017; Dabija et al., 2017). According Ključnikov and Popesko (2017) the export orientation of enterprises represents an important attribute of the enterprises’ competitive ability. In this context, the area of export financing becomes a very important field of company management (Kozubíková et al., 2017; Ključnikov and Belas, 2016).

In relation with entrepreneurial orientation, it means that the company is oriented to be the first in the market in innovation, has the courage to take risks, always be proactive (Lumpkin and Dess, 1996; Kozubíková et al., 2017), and have the principal to identify and exploit opportunities (Lee and Chu, 2011). Nevertheless, the company’s chairman must keep pushing its organization so that all members in the organization have the orientation to continue to learn. This is important because without having the right learning orientation, the company will not be able to implement the organization strategy that has been formulated. If the leader of the company can utilize the existing resources to support



the creation of effective organizational learning and can embrace and understand individuals within the company to organize organizational learning, then organizational learning in the company can work better (Imran et al., 2016) so that it will be useful for a better future (Schein, 1996; Ali Taha et al., 2016). Rose et al. (2010) in her research proves that resource orientation of the company will be able to improve the efficiency and effectiveness of the organization. Some empirical studies have proven that strategic orientation will affect organizational innovation and organizational performance (Obeidat, 2016; Reulink, 2012).

*H1. Environmental Uncertainty (UE) has a significant positive effect toward Resource*

*H2. Environmental Uncertainty (UE) has a significant positive effect toward Market Orientation (MO)*

*H3. Environmental Uncertainty (UE) has a significant positive effect toward entrepreneurship orientation (EO)*

*H4. Environmental Uncertainty (UE) has a significant positive effect toward learning orientation (LO)*

*H5. Research Orientation (RO) has a significant positive influence toward Organizational Innovation (OI)*

*H6. Market Orientation (MO) has a significant positive influence toward Organizational Innovation (OI)*

*H7. Entrepreneurial Orientation (EO) has a significant positive influence toward Organizational Innovation (OI)*

*H8. Learning Orientation (LO) has a significant positive influence toward Organizational Innovation (OI)*

### 3. Research Methodology

This research was conducted on the three largest cement companies with the largest market share in Indonesia. These three companies are required to continue to increase their sales revenue although the current level of competition is very tight. The emergence of several foreign cement companies to Indonesia (Lafarge–Holcim, Conch, China National Building Material and Heidelberg-Inocement) keeps these three companies constantly tidying up from all aspects, especially the aspect of product and service quality given to customers. The population of this research is all 705 managers in 3 large cement companies in Indonesia (top, middle, and lower manager). The sample of this research is mostly managers who work in three different regions in Indonesia, with the sample target of 165 respondents. The sampling technique is using proportional area random sampling. The result of the questionnaire that is proper to be processed and analyzed is 121 questionnaires. The scale technique is using 7 scale of Likert scale, start from score 7 (very strongly appropriate/agree) up to score 1 (very strongly inappropriate/disagree). The statistical technique is using Partial Least Square (PLS). The result of validity and reliability test of the questionnaire shows that it is valid and reliable.

### 4. Research Result

From the results of the data, it can be seen that the majority of respondents are men (67%), age 42-47 years old (41%), working period of 8-14 years (51%), and have bachelor education (62). Table 2 shows that all of the 8 hypotheses path are significant with  $\alpha = 0.05$  and all proposed hypotheses are accepted (sign < 0.05).

Table 2. The Test Result of Inner Model

Hypothesis	Path	Original Sample (O)	Sample Mean (M)	Standard Error (STERR)	T Statistics (O/STERR)	Sig.
1	UE → RO	0.849	0.851	0.025	34.048	0.000
2	UE → MO	0.567	0.572	0.060	9.380	0.000
3	UE → EO	0.424	0.437	0.084	5.064	0.000
4	UE → LO	0.481	0.488	0.061	7.822	0.000
5	RO → OI	0.308	0.300	0.059	5.258	0.000
6	MO → OI	0.264	0.261	0.063	4.164	0.000
7	EO → OI	0.252	0.263	0.062	4.082	0.000
8	LO → OI	0.239	0.241	0.062	3.872	0.000

### 5. Discussion

The cement industry in Indonesia is mostly faced with a very high environmental uncertainty. The three main concerns for managers in the cement companies in Indonesia are; intensity of competition, construction growth, and government regulations. The emergence of foreign cement companies to Indonesia make the domestic cement companies have to struggle and have the agility in capturing the existing opportunities. However, the characteristic of local communities and local culture are become the entry point for the domestic cement companies to be agile and fight smartly in searching new markets and maintaining existing markets (Kustiyadi, 2014). The market outside Java becomes a market that can be used as an alternative to be targeted besides the market in Java that is still very large. It cannot be denied that the previous research result found a unique result, which is the people around the company's location still love to buy cement products with brands that they already know since childhood (Hidayat, 2003;

Kustiyadi, 2014). An area where the cement company is located and the area around the company that has no other cement company (referred to as 'main market') has a very loyal market share with the brand of cement company where the people live (Hidayat, 2003). However, the company must remain focused in improving a good service quality both in the main market and outside the main market. In order to maintain loyal customers, there are various efforts that can be done, for example: fostering, binding, and maintaining loyal customers so that they will continue to conduct repeated transaction and it can affect toward the company performance, both short and long term (Parasuraman, et al., 1985; Zeithaml, 1981). D'Aveni (1994) also adds that the aspect of fixed price war is recommended if the company is faced with a very tight competition dynamics. Therefore, serious efforts are required to overcome the competition intensity by seeking new alternatives outside the main market that has been handled, for example, by strengthening the brand equity outside the main market, competing with competitive price with the competitor companies in the main market, and maintaining market prices in the main market (Hidayat, 2003), and also provide excellent services. These efforts should be supported by strong ownership of resources, capital, technology, and raw material that are still depend on local government regulations and policies.

Resources are still become very valuable asset for companies, especially cement companies. Companies should have unique resources and capability, be different and dynamic because it will be able to improve business performance and organizational innovation (Muafi, 2017; Barney, 1991; Rathinam, 2017). Processed resource must synergize each other to make organization have a high bargaining power if it can process and manage it to be more valuable (Reulink, 2012). Environmental damage that is volatile and hostile requires organization to have a strong organizational agility especially in mobilizing and synergizing their resources to increase business growth. Resource orientation is important for the company manager to empower their resources to be more strategic, highly valuable, and innovative (Reulink, 2012). This is required to meet the market demands that is more dynamic and grow quickly. The industry 4.0 requires the cement industry to have an effective and efficient business model (Ślusarczyk, 2018).

Narver and Slater (1990) emphasize that market orientation must be implemented in a balance way so that the customer can be satisfied and the company performance can increase. Besides customer orientation and competitor orientation, company also have to coordinate between functions in a way; resource and information distribution to all existing business functions and units, all resources must be integrated with company strategy, and must contribute to create customer value. In relation with entrepreneurship orientation, Covin and Slevin (1989) suggest that companies continue to implement an effective management practice. Managers must have proactive behavior, autonomy, risk-taking, innovativeness, and competitive aggressiveness. This is because managers' behavior will be able to increase the growth of company business and organizational innovation (Covin and Slevin, 1989; Muafi, 2009b). All members of organizations and managers must also have shared vision, commitment to learn, and open mindedness orientation to achieve the goal of the organization. Hurley and Hult (1998) emphasizes learning orientation as a precursor in explaining the company culture into innovation. Organizational learning is considered as a process where the organization change or modify their mental models, process, rules, behavior, or knowledge (Chiva and Habib, 2015). The culture of organizational learning needs to be created because it is a factor that can improve organizational innovation, company performance, and individual performance in the company. This needs a strong and consistent commitment from all stakeholders to maximize the capability in the digital transformation of industry 4.0. Cement companies must have a high entrepreneurship and continue to do a learning process continuously, especially from technological aspect. This is because in the future, all products and services offered by competitors are based on technology. The technology that is offered should be effective in the use of time or cost allocation, so that the company can produce and offer their products and services efficiently and effectively. The impact is that the products and services that are offered can be cheaper but still have a good quality and can compete in domestic and foreign market.

The limitation of this research is the research object that is too narrow, because it is only test three biggest objects of the cement companies, so it is feared to be not really able to generalize cement companies in Indonesia. The managers of the cement companies that are researched should be taken by considering work experience and age because those are related to the strategic decision making of the company. For future research, researcher should use a thorough in-depth interview, so that they can use mix method approach (quantitative and qualitative). Besides, it is better to use longitudinal method instead of cross section, so that the result can be more accountable, because it includes the aspect of strategic decision making in a big company

## References

- Ali Taha, V., Siriková, M., Ferencová, M., The Impact of Organizational Culture on Creativity and Innovation, *Polish Journal of Management Studies*, Vol.14, No.1, pp. 7-17, (2016).
- Barney, J.B., Firm resources and sustained competitive advantage, *Journal of Management*, Vol.17, No.1, pp. 99-120, (1991).
- Carvalho, C.E., Rossetto, C.R., Verdinelli, M.A., Strategic Orientation as a Mediator Between Environmental Dimensions and Performance: A Study of Brazilian Hotels, *Journal of Hospitality Marketing & Management*, Vol.25, Iss.7, pp. 870-895, (2016).

- Castrogiovanni, G.J., Environmental Munificence: A Theoretical Assessment, *The Academy of Management Review*, Vol.16, No.3 (July), pp. 542-565, (1991).
- Chiva, R., Habib, J., A Framework for Organizational Learning: Zero, Adaptive and Generative Learning, *Journal of Management and Organization*, Vol.3, pp. 350-368, (2015).
- Choe, J., The effect of environmental uncertainty and strategic application of IS on a firm's performance, *Information and Management*, Vol.40, pp. 257-268, (2003).
- Covin, J. G. and Slevin, D.P., Strategic Management of Small Firms in Hostile and Benign Environments, *Strategic Management Journal*, Vol.10, No.1, pp. 75-87, (1989).
- Dabija, D.-C., Pop, N. Al., Săniută, A., Innovation in Do-It-Yourself Retail: an Empirical Study on Generation X among Professional Craftsmen and Consumers, *Economics and Sociology*, Vol.10, No.2, pp. 296-311, (2017).
- D'Aveni, R., *Hypercompetition: Managing the Dynamics of Strategic Manuevering*, New York: The Free Press, (1994).
- David, F.R., *Strategic Management. Concept and Cases*. Pearson Education, New Jersey: Prentice Hall, (2001).
- Deshpande R., Webster, F.E.Jr., Organizational culture and marketing: Defining the research agenda, *Journal of Marketing*, Vol.53, No.1, pp. 3-15, (1989).
- Deshpande, R., Farley, J.U., Webster, F.E. Jr., Corporate Culture, Customer Orientation and Innovativeness in Japanese Firms: a Quadrad analysis, *Journal of Marketing*, Vol.57, No.1, pp. 23-37, (1993).
- Dess, G.G., Beard, D.W., Dimensions of organizational task environments, *Administrative Science Quarterly*, Vol.29, pp. 52-73, (1984).
- Duncan, R., Characteristic of Organizational Environmental and Perceived Environment Uncertainty, *Administrative Science Quarterly*, Vol.17, No.3, pp. 313-327, (1972).
- Elbanna, S., Alhwarai, M., The Influence Of Environmental Uncertainty And Hostility On Organization Performance, *working paper series, Faculty of Business and Economics*, UAEU, (2012).
- Elbanna, S., The impact of affective conflict on firm performance, *Management Research Review*, Vol.32, No.9, pp. 789-803, (2009).
- Gatignon, H., Xuereb, J-M., Strategic Orientation of The Firm and New Product Performance, *Journal of Marketing Research*, Vol.34, No.1, pp. 77-90, (1997).
- Grant, R.M., *Contemporary strategy Analysis*, (4<sup>th</sup> ed.), Oxford: Blackwell Publishers Inc., (2002).
- Hakala, H., Strategic Orientations in Management Literature: Three Approaches to Understanding The Interaction Between Market, Technology, Entrepreneurial and Learning Orientations, *International Journal of Management Reviews*, Vol.13, No.2, pp. 199-217, (2011).
- Hidayat, I., *Pengaruh Faktor Lingkungan Makro, Lingkungan Industri dan Lingkungan Internal Terhadap Marketing Strategies dan Kinerja Perusahaan*, Disertasi, Universitas Brawijaya, Malang, (2003).
- Hodge, B.J., Anthony, W.P., Gales, L.M., *Organization theory: A strategic approach*, (6<sup>th</sup> ed.), New Jersey: Prentice Hall, (2003).
- Hurley, R.F., Hult, T.M., Innovation, Market Orientation, and Organizational Learning: An Integration and Empirical Examination, *Journal of Marketing*, Vol. 62, pp. 42-54, (1998).
- Imran, M.K., Ilyas, M., Aslam, U., Organizational Learning Through Transformational Leadership, *The Learning Organization*, Vol.23, Iss.4, pp. 232-248, (2016).
- Jonek-Kowalska, I., Coal mining in Central-East Europe in Perspective of Industrial Risk, *Oeconomia Copernicana*, Vol.8, No.1, pp. 131-143, (2017).
- Jones, G.R., *Organizational Theory, Design, and Change*, (5<sup>th</sup> ed.), New Jersey: Pearson International Edition, (2007).
- Kean, R., Gaskill, L., Leistritz, L., Jasper, C., Bastow-Shoop, H., Jolly, L., Sternquist, B., Effects of Community Characteristics, Business Environment, and Competitive Strategies on Rural Retail Business Performance, *Journal of Business Management*, April, pp. 45-57, (1998).
- Kljucnikov, A., Belas, J., Approaches of Czech Entrepreneurs to Debt Financing and Management of Credit Risk. *Quarterly Journal of Economics and Economic Policy*, Vol.11, No.22, pp. 343-365, (2016).
- Ključníkov, A., Popesko, B., Export and its Financing in The SME Segment. Case Study From Slovakia, *Journal of Competitiveness*, Vol.9, Iss.1, pp. 20-35, (2017).
- Kohli, A.K., Jaworski, B.J., Market Orientation: The Construct, Research Propositions, and Managerial Implications, *Journal of Marketing*, Vol.54, No.2, pp. 1-18, (1990).
- Kozubíková, L., Sopková, G., Krajčík, V., Tyll, L., Differences in innovativeness, proactiveness and competitive aggressiveness in relation to entrepreneurial motives. *Journal of International Studies*, Vol.10, No.4, pp. 207-218, (2017).
- Kozubíková, L., Homolka, L., Kristalas, D., The Effect of Business Environment and Entrepreneurs' Gender on Perception of Financial Risk in The Smes Sector, *Journal of Competitiveness*, Vol.9, Iss.1, pp. 36-50, (2017).
- Kustyadi, G., *Peran Budaya Menuju Keunggulan Bersaing Pasca Konsolidasi BUMN*, Disertasi, Universitas Brawijaya, Malang, (2014).
- Lee, T., Chu, W., Entrepreneurial Orientation and Competitive Advantage: The Mediation of Resource Value and Rareness, *African Journal of Business Management*, Vol.5, No.33, pp.12797-12809, (2011).
- Li, H., How does new venture strategy matter in environment-performance relationship?, *Journal of High Technology Management Research*, Vol.12, Iss.2, pp. 183-204, (1991).
- Lukas, B. A., Tan, J.J., Hult, G.T.M., Strategi fit in transitional economies: The case China's electronics industry, *Journal of Management*, Vol.27, Iss.4, pp. 409-429, (2001).

- Lumpkin, G.T. & Dess, G.G. (1996). Clarifying the entrepreneurial orientation construct and linking it to performance. *Academy of Management Review*, Vol.2, No.1, pp. 135–173, (1996).
- Luo, Y., Environment Strategy Performance Relation in Small Business in China: A Case of Township and Village Enterprise in Southern China, *Journal of Small Business Management*, Vol.37, No.1, pp. 37-52, (1999).
- Mahmud, M., Aryanto, V.D.W., Hasyim, H., The Effect of Innovation Capability and New Product Development on Marketing Performance of Batik SMEs, *Polish Journal of Management Studies*, Vol.15, No.2, pp. 132-142, (2017).
- Manu, F.A., Sriram, V., Innovation, Marketing Strategy, Environment and Performance, *Journal of Business Research*, Vol.35, No.1, pp. 79-91, (1996).
- Muafi, A Configuration And Contingency Approach To Understanding Export Performance, *International Review of Business Research Papers*, Vol.5, No.2, pp. 358-369, (2009a).
- Muafi, The effects of alignment competitive strategy, culture, and role behavior on organizational performance in service firms, *Int. Journal of Organizational Innovation*, Vol.2, No.1, pp. 106-134, (2009b).
- Muafi, Is there a relationship pattern between small medium enterprise strategies with performance in technology business incubator?, *Int. Journal of Public Sector Performance Management*, Vol.3, No.1, pp.18-39, (2017).
- Narver, J.C., Slater, S.F., The Effect of a Market Orientation on Business Profitability, *Journal of Marketing*, Vol.54, No.4, pp. 20-35, (1990).
- Obeidat, B.Y., The Effect of Strategic Orientation on Organizational Performance: The Mediating Role of Innovation, *International Journal. Communications, Network and System Sciences*, Vol.9, pp. 478-505, (2016).
- Parasuraman, A., Zeithaml, V.A., Berry, L.L., A Conceptual Model of Service Quality and Its Implications for Future Research, *The Journal of Marketing*, Vol.49, No.4 (Autumn, 1985), pp. 41-50, (1984).
- Pilat, M., How Organizational Culture Influences Building a Learning Organization, *Forum Scientiae Oeconomia*, Vol.4, No.1, pp. 83-92, (2016).
- Rathinam, M., Management Innovation Capabilities: A Case Study of a Rail Organisation, *Polish Journal of Management Studies*, Vol.16, No.2, pp. 243-252, (2017).
- Reulink, R.B.J., *Strategic orientation and innovation performance at Dutch manufacturing SME's: The overrated role of Market Orientation and Entrepreneurial Orientation*, Thesis, Universiteit Twente, (2012).
- Robbins, S.P., *Organization Theory. Structure, Design and Application*, (3<sup>rd</sup> ed.), New Jersey: Prentice Hall, (1994).
- Rose, R.Che., Abdullah, H., Ismad, A.I., A Review on the Relationship Between Organizational Resources, Competitive Advantage and Performance, *The Journal of International Social Research*, Vol.3, No.11, Spring, pp. 488-498, (2010).
- Schein, E.H., Three Cultures of Management: The Key to Organizational Learning, *Sloan Management Review*, Vol.38, No.1, pp. 9-20, (1996).
- Shane, S., Kolvereid, L., National Environment, Strategy, and New Venture Performance; A Three Country Study, *Journal of Small Business Management*, April, pp. 37-50, (1995).
- Simerly, R.L., Li, M., Environmental Dynamism, Capital Structure and Performance: A Theoretical Integration and Empirical Test, *Strategic Management Journal*, Vol.21, No.1, pp. 31-49, (2000).
- Sachpazidu-Wójcicka, K., Innovation as a Determinant of the Competitiveness of Polish Enterprises, *Oeconomia Copernicana*, Vol.8, No.2, pp. 287-299, (2017).
- Szczepańska-Woszczyna, K., The importance of organizational culture for innovation in the company, *Forum Scientiae Oeconomia*, Vol.2, No.3, pp. 27-39, (2014).
- Ślusarczyk B., Industry 4.0 - Are We Ready? *Polish Journal of Management Studies*, Vol.17, No.1, pp.232-248, (2018).
- Ward, P.T., Duray, R., Leong, G.K., Sum, C.C., Business Environment, operation strategy and performance: An empirical study of Singapore manufacturers, *Journal of Operation Management*, Vol.13, No.2, pp. 99-115, (1995).
- Zahra, S.A., Neubaum, D.O., Huse, M., The effect of the environment on export performance among telecommunications new ventures. *Entrepreneurship Theory and Practice*, Vol.22, No.1, pp. 25-46, (1997).
- Zeithaml, V.A., How Consumer Evaluation Processes Differ between Goods and Services, *Marketing of Services, Journal*, pp. 186-190, (1981).

## Aspects of Organisational Culture and Change Management

Elena-Izabela Popa<sup>a\*</sup>, Eduard Edelhauser<sup>a</sup>, Eugenia Jornea<sup>a</sup>

<sup>a</sup> University of Petrosani, Universitatii street, No. 20, Petrosani, 332006, Romania

---

### Abstract

Effective adaptation of organisations regarding the competitive environment involves undergoing a process of important changes which must take into account the organisational culture, which is an essential component of an organisation's transformation process. In order to meet the demands which must be made and to become efficient, organisations need to pay more attention to the organisational culture. Organisational culture can become a factor that either facilitates or prevents the adaptation process. Therefore, regular evaluation and changing the organisational culture become real and important. Changing the organisational culture represents a far-reaching activity due to each organisation's culture containing a set of objectives, roles, processes, values, communication practices, attitudes and hypotheses. These are the implementation tools for achieving the desired results. In this context, this paper addresses a topic that has been little explored in the Romanian specialty literature: to establish a possible link between the organisational culture, the resistance to change and the performance of an organisation.

To make a first pragmatic approach to the research topic, we have conducted a case study on organisational culture assessment at an organisational level within a power generation company.

*Keywords:* organisational culture; improvement; management; performance; change.

---

### 1. Introduction

Discovering the importance of two essential elements in the functioning and the development of an organisation – the importance of employees and the socio-human climate – represented the debut of organisational and managerial theories.

Any organisation has two “universes” among which we need to make a clear distinction. One of them is represented by employees, the relations between them, the level of training they have, manifest and apply, the values they adhere to and they expose as a reference in their relations with the surrounding world, and the other universe is made up of cars and technology, the production processes, the productivity and competitiveness of the products and services offered, and the market.

It is already well known that society reflects the “states” that organisations face. In this sense there are expressions at a national level – society is largely the expression of what exists, happens, develops or changes in the organisational space (Vlăsceanu, 1999) – and also at an international level – the organisation is an important marker of the contemporary age, and society represents the mirror of the organisations that make it up (Drucker, 1999).

Organisations are perceived as “*social inventions designed to achieve common goals through group effort*” (Johns, 1998), as social structures formed of groups of individuals acting in a coordinated and unitary way to achieve their goals. Regardless of their type (private, state, profit/non-profit, economic etc.), organisations function under the impact of certain values; in other words, each of them possesses a certain organisational culture. To know an organisation's culture is to understand how it works, the cultural factor having an important influence on management policies.

Hence, besides the structure, economic processes and people, an important element of an organisation is **culture**. We must distinguish between the culture seen as a very broad concept (mentality being one of its components) and **organisational culture**.

---

\*Corresponding author. Tel.: +40720666187  
E-mail address: izapopa1974@yahoo.com

## 2. Organisational culture: evolution, concept, and approach over the years

Organisational culture represents a relatively new concept; it has become a discussion and analysis topic in the recent years. Just 40 years ago organisational culture has been introduced in the managerial field. After only 10 years of existence it came to the attention of schools and universities.

Although concepts such as “group norm” and “climate” have been used since 1939 (Lewin, apud. Schein, 1990), organisational culture has been explicitly used over the past decades.

Since the 1970s, organisational research has started to use cultural concepts in organisational behaviour analysis.

The phrase “*organisational culture*” was introduced in specialty literature in 1979 by Pettigrew in his paper “*On studying organisational culture*”. Pettigrew conducted a study on the evolution of an English school under the influence of events that were perceived by the organisation’s members as critical events, from its establishment in 1934, until 1975, when the author collected the latest data.

There has been a significant increase in the popularity of organisational culture starting in the 1980s; relevant to this were the pieces of work of Terrence Deal and Allan Kennedy (1982) “*Corporate culture: The Rites and Rituals of Corporate Life*”, “*In Search of Excellence: Lessons from America’s Best Run Companies*” of Thomas Peters and Richard Waterman (1982), and also “*Culture’s Consequences*” of Geert Hofstede (1980); the coming out of these works triggering an explosion of research on the concept of organisational culture.

After 1990s, the emerge of investments from multinational companies in Eastern Europe countries made the concept of organisational culture known in this part of the world.

Organisational culture arises out of the need for concepts that differentiate organisations of the same society, especially in relation to efficiency levels. This concept semantically integrates the values, symbols, believes, myths, rituals, ceremonies, and aspirations that define the spiritual space of an organisation (Burlacu and Cojocaru, 1999).

Currently, taking these aspects into account, the understanding and using of the concept of organisational culture, it has become necessary as a tool within a company, in the case when a company targets a top position in the ranking of the field which it operates in.

## 3. Case study within Oltenia Energetic Complex

Oltenia Energetic Complex (CE OLTENIA) is a mostly state-owned company, a major player on the Romanian energy market, being the largest electrical energy producer using fossil fuel.

The Romanian energy market is constantly changing and the energy consumption has fluctuations of more than 40% even in the spare of a week. Under these circumstances, the organisation’s status recommends that changes be implemented immediately and consistently across the organisation’s structure.

The quality of being the leader of vocational training activity within CE OLTENIA and that of being the first author of the paper has determined me to initiate a research project regarding organisational culture and, together with the co-author of this paper, to establish a possible link between the organisation of culture, resistance to change and the performance of an organisation.

We believe that the change of organisational culture plays a crucial role in the rapid adaptation of the organisation to the external changes it faces. First, the managers’ resistance to change must be defeated, as organisational culture represents “the result of the effort of managers to guide staff in the spirit of excellence” (Edelhauser, 2011).

If the paradigm of change can also be a change of paradigm, we can conclude that “in order for the world to be different, we must also change the paradigm” (Abrudan, 2012).

The aim of this paper is to make an assessment of the organisational culture in CE OLTENIA, to show that the main element leading to the valorisation and development of the organisation is the continuous improvement through *change*.

A case study will be carried out throughout this paper; it is not representative of Romania, but it is only a trend reflected by electric energy company, within which the issue of the evaluation of the organisational culture and its impact on long term performance was raised.

The data used comes from CE OLTENIA, a company which has undergone restructuring and *change* programs.

The sample this research was conducted upon is representative of technic economic socio-administrative and managerial staff.

The research conducted aims at assessing the organisational culture, highlighting the specificity of the culture within CE OLTENIA, observing whether organisational culture is viewed within the organisation as a powerful strategic tool used to guide the company and all its employees towards common goals, to mobilise the employees’ initiative, to ensure loyalty and ease the communication between them. It has been analysed whether the organisational culture is understood by employees and whether they fully adhere to it, but also the connection between this concept and the human resource of this society.

### 3.1. Research methodology

The *research method* used was the *survey based on a questionnaire*. The *questionnaire* helps determine organisational culture and assess it in terms of employee behaviours and the way they perceive whether they match the organisation they belong to and whether their expectations are met.

Performing a research program, regarding the conduction of the survey, is essential for estimating the cost and the time needed to take steps to ensure the effectiveness of the study.

In the realisation of the survey as a methodological tool, *the questionnaire* used was the one applied in CE OLTENIA between the 14<sup>th</sup> of May and 15<sup>th</sup> of June 2018.

In order to avoid the *halo effect* (employee's tendency to respond similarly to multiple questions), a lean presentation of the study was chosen without delimiting by title the category or dimensions the question was looking for.

*The questionnaire* consists of 30 open, close, and multiple answers questions.

*The questionnaire* contains in the beginning a brief overview of its subject, and then it is structured in two parts.

*Part I of the questionnaire* is generically titled *Identification Data* and it consists of a set of nine general questions in order to ease the entry into the subject.

*Part II of the questionnaire* is generically titled *Enterprise values evaluation data* and it consists of a set of 21 questions introduced in order to determine what are the values, norms, ethical principles of the organisation and the extent to which employees adhere to the society's values, objectives, policies.

The choice of *scales* for this type of questions (with scale) was made according to the studied variable, hence avoiding the generation of appreciation errors (the tendency to give neutral or contradictory answers).

*The types of scales* frequently used in *the questionnaire* are *nominal scales*, namely *dichotomous* with answers such as *yes, no, neutral*, and with *a possible answer from a given list*.

In *the questionnaire* there were also used questions with an *ordered scale* with *the hierarchy of preferences* (from most important to least important), *Likert* (from total agreement to total disagreement), *questions with differentiated scales by importance* (from a lot to not at all).

The following criteria have been applied to the applied *research method*: accuracy of results, cost, timing, nature of reference population, sample size, available information.

The advantages that support the efficiency of the chosen method are: the facilitation of the extraction of the employees subject to the study, the possibility of a rigorous control of the data collection process, a low cost and a limited time for sample determination.

In the interest of ensuring the confidentiality of the information regarding the respondents in order to increase the accuracy of the data obtained, their names were not specified, but only their position within the company, their gender, and their age, to which it is added the seniority in the company.

### 3.2. The population and sample observed

The population under investigation is made up of 50 employees from the personal management and execution categories of CE OLTENIA. The age of the respondents varies between 35 and 55 years and regarding their gender, they are both women and men. The questionnaire was distributed through direct contact to employees in different positions and functions.

### 3.3. Analysis and interpretation

*Questionnaire* survey data were collected, processed, analysed, and interpreted between May 14<sup>th</sup> and June 15<sup>th</sup> 2018.

All 50 *questionnaires* were correctly completed, these being the subject of statistical analysis.

For data processing, the program used was *Statistical Package for the Social Sciences – SPSS*, one of the most used programs in statistical analysis of data. This program has been favoured not only by availabilities, but also by the fact that it offers a larger flexibility in the case when the desired information is predominantly of quantitative nature, which has made it data recording and analysing easier.

It is not excluded that the results of this research may contain possible errors due to lack of field experience.

### 3.4. Results

The centralised data shows that CE OLTENIA is an organisation oriented towards respecting ethical principles, values, promoting a customer-oriented attitude.

The society's mission is *to produce efficient, clean and safe electricity, based on exploiting the lignite potential with maximum efficiency in Oltenia, to ensure Romania's energy security.*

The company's motto is *Excellence through quality.*

The company's slogan is *OLTENIA ENERGY COMPLEX – ROMANIAN LAND'S ENERGY.*

Behavioural rules: *immediate execution of the orders of bosses, respect of discipline and order, ethical behaviour and integrity, assuming responsibility and consequences for the committed deeds, teamwork* are respected by the employees.

*The sources of information regarding the values of the company* are represented through the following: official website, internal communication network, intranet, publication edited by CE OLTENIA, regular meetings and training with the employees, company regulations. The organisation has a preference for oral communication, although it is present within the society the written communication highlighted through procedures, instructions, and company regulations.

There is also a *desire* within the society *to avoid conflicts by reaching a compromise.*

Staff adheres to the organisation's goals and policies, showing loyalty to it. Sources of information regarding company values are represented by: internal regulation; code of ethics; organisation and operations regulations; system, administrative, and operational procedures; regular meetings and training with employees.

On the other hand, it can be said that, *after contributing to performances*, CE OLTENIA falls into the category of *forte culture* or *positive culture* characterised by the homogeneity of values and perspectives that provide positive motivation.

*According to the accepted risk level and the speed of obtaining feedback*, CE OLTENIA falls into the Process culture category, being a rigid culture, based on rules and procedures. Employees are disciplined, orderly, punctual and thorough.

Furthermore, *according to the type of transaction by which the individual is linked to the organisation*, it can be concluded that CE OLTENIA belongs to the *hierarchical culture* type because it is based on employees respecting procedures and regulations in an environment of stability and control. In CE OLTENIA the authority lays in the rules and the power is executed by specialists. Decisions are based on detailed analyses, and leaders tend to be conservative and cautious.

*According to the organisation's configuration*, CE OLTENIA falls into the *Role culture (temple type)* due to it being a large society, with bureaucratic mechanisms which determine the appearance of subcultures in specialised departments, which form the column on which the temple rests; the values and perspectives, given by the roof of the temple, are clear, expressed in writing, with an obvious tendency towards stiffening, discipline, respect of codes, instructions, procedures, regulations of society, individuals are offered the possibility of professional specialisation.

*Depending on organisations' characteristics and the differences between the national cultures*, CE OLTENIA falls within the *Eiffel Tower culture type*, because the relations between the employees are regulated in advance by imposed interactions; authority is attributed to the most important roles, people being distant but very powerful.

CE OLTENIA is a *collectivist society*, due to it favouring interdependence, loyalty to a family or clan with a feminine culture because it accepts different roles regarding genders, emphasizing gender equality.

Within CE OLTENIA the following are emphasised: rules, regulations, hard work, compliance, safety, which, in terms of *avoiding incertitude* (the degree of assuming risks, the degree to which the employees feel uncomfortable in uncertain and ambiguous situations), make it fit in strong avoidance.

Taking into account the orientation, CE OLTENIA fits into *long-term oriented cultures*, as it emphasises perseverance, prudence, attention to position differences.

CE OLTENIA falls into the type of organisations characterised by a *small distance from power*, within which: inequality is minimized, superiors are accessible, and power differences are not given great importance.

*In a proportion of 90%, employees are identified with the organisation's values and they adhere to the company's objectives and policies.*



#### 4. Conclusions

The result of the research shows that CE OLTENIA represents an organisation that *promotes a customer-oriented attitude and values*.

The most important *values* promoted by CE OLTENIA are: professional excellence, team spirit, solidarity, valorisation of synergies, ethics, integrity and loyalty, fairness and respect, standard of business ethics (internal and external) towards colleagues, customers, providers, the respect and responsibility towards the community and environment.

Therefore, it can be concluded that the *hypotheses of this research on the organisational culture of CE OLTENIA are valid* because the moral values have an impact on the performance of the organisation and its employees. There are no differences between the values promoted within the company and those in which employees find themselves. Ethical behavioural values and norms are promoted within the organisation.

*Organisational culture* promoted within society is known and understood by the organisation's employees. Employees' values match the requirements of organisational culture promoted within the company.

*Organisational culture* represents a combination of conscious and unconscious, rational and irrational, group and individual elements, which influence each other and have a major impact on the functionality and performance of the society.

Society culture is a support in orientation, essential for both managers and employees, it is a source of identification and it creates a sense of security and refuge.

Any organisation can be seen as a social structure, consisting of a group of people who act together to achieve the organisation's goals. The success of an organisation is conditioned by the extent to which the personnel act as a whole in order to achieve its goals.

Quality-oriented *organisational culture* is a guarantee of continuous survival and development for any organisation, regardless of whether it operates in a highly competitive market or in an unfavourable economic, social, or politic environment.

This is because the organisational culture, through its components, dictates certain rules of employee behaviour, guides how the employees perceive and represent reality, how they should react to environmental changes.

The existence of an organisational culture involves the transmission and learning of a behavioural type that must become a habit for the employees. By the way they behave on a daily basis; managers encourage employees to adopt an identical behaviour in their relations with others.

If the society imposes through its own culture behaviours that lack ethics, not only will the leadership behave this way, but also the employees, taking the managers as an example.

Within an organisation with an authoritarian management, an organisational culture lacking values and moral principles, employees will also adopt an immoral behaviour.

*Organisational culture* has become fashionable topic in the recent years, a topic that has been frequently approached both in the academic world and in the economic environment. Its importance is mainly reflected by the impact it has on the results of an organisation.

Thus, regardless of whether we are talking about a public institution, a state owned company, or a foundation, we can definitely affirm that a healthy organisational culture is a safe chance for success; it is one of the main factors that can determine the performance of that organisation.

#### References

- Abrudan I., *Cultura managerială/Managerial Culture*, Editura Digital Data, Cluj-Napoca, (2012).
- Burlacu N., Cojocaru V., *Management*, Chişinău, (1999).
- Drucker P. F., *Management Challenes for the 21ST Century*, (1999).
- Edelhauser E., *Tendenţe ale utilizării metodelor avansate în managementul organizaţiilor româneşti*, coordonator prof. univ. dr. Burlea Şchiopoiu Adriana, teză de doctor în domeniul fundamental Ştiinţe Economice, Domeniul de doctorat Management, Craiova, (2011).
- Hofstede G., *Culture's Consequences: International Differences in Work-Related Values*, Beverly Hills, Sage, (1980).

Johns G., *Comportament organizațional*, Editura Economică, București, (1997).

Lewin K., *Field Theory in Social Science*, Harper&Row, New York, (1997).

Peters T.J. si Waterman R.H., *In Search of Excellence: Lessons from America's Best Run Companies*, Harper & Row, New York, (1982).

Vlăsceanu M., *Organizații și comportament organizațional*, Editura Polirom, Iași, (1999).

# Integration of Human Resources Strategy in the General Strategy of an Enterprise

Ioan Rus

University of Petrosani, University Str. no. 20, Petrosani, Romania

---

## Abstract

*Starting from the definition of human resources management, the activities carried out within the human resources management, the difference between the personnel management and the human resources management are explained, and the connection between the human resources management and the strategic management of an organization is presented. Similarly, the paper establishes the role played by the human resources manager in the organization, the new tendencies in human resources management are presented, and the means of assessment of human resources management are explained.*

*Keywords: human resources management; personnel function; human resources manager; human resources strategy.*

---

## 1. What is human resources management?

Human resources management is the process as a result of which the employees obtain the desired level of satisfaction, and the organizations to which they belong reach their proposed goals, by harmonizing four elements: environment, organization, job, and employee.

1) The organization exists within the environment and only survives if it efficiently interacts with it. The *environment* has four components:

- ✓ *Economic component* (number and competitive force of organizations, unemployment rates, interest rates, inflation etc.)
- ✓ *Social component* (values and attitudes of customers and employees as far as work, products, businesses, aptitudes, educational level, their expectations are concerned)
- ✓ *Political component* (laws and regulations)
- ✓ *Technological component* (raw material, technology).

2) The *organization* should provide, by its characteristics, employees' satisfaction and performance. These characteristics are: dimension, structure, technology, culture.

3) *Jobs* are the entirety of tasks and activities of an employee. Job characteristics influence the employees' performances and satisfaction. These characteristics are: degree of difficulty, variety, autonomy offered to employees.

4) The *employee* brings to the organization a set of his own characteristics. The good performances of an employee in a certain job depend on: aptitudes, knowledge, personality, values, and expectations.

All these four elements have experienced important modifications in the last years.

## 2. From personnel management to human resources management

Personnel function came up in an organization as a result of:

- Increase of its dimension;
- Increase of number and complexity of legal regulations regarding personnel;
- Modifications occurred in the social component of the environment.

In several organizations the titles of chief or director of personnel are maintained. These manage the following activities: creating jobs; recruitment and selection; orientation; training and specialization; assessment of performances; work compensation; career management; labor protection; motivation of employees; management of labor conflicts.

The responsibilities of the human resources managers include a wider range, implying their direct involvement in the process of development, implementation, control and modification of strategies, as well as counseling in problems connected to a good management of the human resources.

Considering the tight connection that should be between human resources management and strategic management of an organization, we consider that it is necessary:

- On the one hand, for the human resources managers to know the elements of the strategic management;
- On the other hand, for the general directors and other managers of an organization to know the activities that should be covered related to the organization's personnel.

In organizations of over 100 employees, managers and specialists in the compartments of human resources coordinate and /or cover the specific activities, mentioned above. These activities imply the involvement of all the managers of organizational links, which during the activities should work in team with the first ones. Together, the managers from the human resources compartments and the other managers of the enterprise should:

- Establish the goals and objectives of the organization;
- Develop and implement strategies;
- Monitor their efficiency and modify them, so that they should be adapted to the environment.

### 3. Connection between human resources manager and strategic management of an organization

The pressure exerted by the environment on the organization made the increase of the involvement of the human resources specialists in the strategic management process, necessary.

The long-term strategy of an organization establishes future directions such as increase of incomes, of market quotas, cost reduction or diversification in another field of activity. Therefore, long-term, large-scale plans, regarding recruitment and selection of new employees, training of the existing ones, or dismissal of employees that are no longer adequate to the necessities of an organization, are necessary. Consequently, the human resources director develops the human resources strategy, which is then forwarded to the Administration Board to be approved, the personnel categories to be employed being established, as well as the funds to be allocated for recruitment – selection and training – specialization, so that the enterprise should have sufficient competent personnel at the right moment.

When the strategy has been established, the specialists from the human resources compartment develop concrete action programs, such as develop documents required for recruitment, and organize visits in university campuses, interview candidates, employ and train. In all these activities, they closely cooperate with the managers of the operational links. Strategic management of human resources is the process by which the human resources management connects to the general strategy of the enterprise, in view of accomplishing the organization's goals and objectives.

The human resources strategy is that part of the general strategy of the enterprise which strictly refers to human resources function; therefore, it is a functional strategy.

As in the case of general strategy of the organization, in the strategy of human resources *decisions are made on three levels*:

- *At strategic level*, the general director and the human resources manager establish long-term directions, such as career management, rewards policies;
- *At managerial level*, long-term plans are concretized by developing concrete programs, for example recruitment program of training program;
- *At operational level*, the concrete programs developed are implemented. Salaries are paid, as well as other reward forms, courses and other forms of training and perfecting are organized, recruitment and selection of personnel is done. The strategy should be developed in time, and not as a reaction to the upcoming crises. Thus it has to be *pro-active*, not *reactive*. The more the human resources managers are involved in the strategy development stage, the less will the crises be, for the solving of which they would have to provide assistance.

Human resources strategy is adopted in such a way as to achieve harmonization between the individual, job, organization and environment, by *five principal policies*:

- Assurance policy for the necessary staff by employment;
- Performance management policy;
- Employees' development policy;
- Reward – motivation policy;
- Organizational change policy.

*Four human resources strategy types* can be adopted, function of the job situation, on the one hand, and on the employees' situation on the other.

- *Stable employee – stable job*. This combination involves choosing the employee corresponding to the job. The most important policy is the employment policy, by recruitment, selection, orientation activities.
- *Flexible employee – stable job*. In this situation, the activity and performances of the employee should be altered so that he /she would acquire knowledge, aptitudes attitudes required for the accomplishment in the best conditions of the job requirements. Performance management and employees development policies become fundamental by assessment, training, coaching, mentoring activities

- *Stable employee – flexible job.* In this case, the situation of the job should be modified regarding the requirements, work or reward conditions to correspond to the employees' demands. The activities involved are job planning, negotiations with the Unions, altering work reward and motivation programs, health and labour protection programs.

- *Flexible employee – flexible job.* This time both components are modified. In this situation, all policies and all human resources activities, which are continually changing and mutually influence each other, are applied.

In order to see what is the relationship between the employee and the job, a thorough analysis of the two components: job and employee should be made.

- *Job analysis* studies the activities, attributions and work conditions involved, the knowledge, aptitudes and attitudes required for the employees' adequate performances and the relationships with other jobs.

- *Employees' analysis* involves studying their previous performances, their potential as well as their necessities, desires and values.

In view of accomplishing the established objectives, it is necessary for the human resources strategy of the organization to be developed and monitored by the entire staff of the organization, and the top management of the corporation and the human resources managers should closely cooperate. A special attention is needed for domains that demand special talents and for events that significantly affect human resources, such as: geographic extension, introducing products and services, increase of automation level, mergers and acquisitions, to see if there are or can be trained specialists in the respective labour markets. Factors affecting human resources management should be considered, such as: economic, demographic, social, political ones, as well as modification of branch configurations. The organization's units should be regarded in their interdependency, so that together they might contribute to the accomplishment of the organization's objectives. It is absolutely necessary to review periodically the developed strategy, making the necessary modifications, in view of adapting them to the environment.

Human resources strategy represents a combination of the approaches described above, depending on the stage in the life cycle through which the organization moves.

*In the stage of creation of the organization,* preponderant is the policy of the personnel assurance, by hiring staff having entrepreneurial aptitudes, enthusiastic, adaptable to the founder's vision and ready to perform a relatively low complexity, but intense activity. In this stage, the entrepreneur has many current tasks to solve and neglects planning. It is dangerous not to be preoccupied with the future of the employees, which will become necessary in the future. Cash is scarce in this period, therefore the employees accept either to be paid less, the difference being paid at a future date, or to receive social parts or shares to the enterprise.

*In the stage of organization development,* recruitment and selection of the personnel are equally important, but should become more rigorous, looking for specialists in certain field of activity, which would develop alongside with the organization. The training activity becomes very important, because it allows the personnel to respond to higher exigencies and to implicitly advance in better jobs. Rewards should stimulate the personnel into acting in view of development, bonuses being very important in this stage. Since rewards should be well correlated with the employees' performances, personnel assessment systems become especially important. Rewarding loyalty can result in retaining in the organization inadequate persons, which will lead to disastrous effects in the maturity stage.

*In the maturity stage,* activities become better and better structured. Specialized compartment come into being, and work procedures are standardized. Recruitment and selection are no longer vital, as in the previous stages, but rewarding work and personnel development become a priority, as means of motivating and obtaining performances. Rewards can be in the form of fixed salaries. Personnel development is especially important, since creativity has to be stimulated, without which the enterprise is in decline. The more new products and services would be discovered and the existing ones would be improved, the longer the maturity period would be, both in the benefit of the employees, and of the founders.

*In the decline stage,* the choice of the reward type becomes particularly important. The employees are rather frustrated because of the sombre future; therefore the work itself does no longer bring them satisfaction. When the objective of the organization becomes gradual liquidation, it would be unfair for the pay to be correlated with the performances of the organization. Moreover, if rewards are function of the profit, the unwanted situation would arise, when the employees would act to increase it. Therefore, monetary compensations should be correlated with how the employee fulfils his/her tasks, incentives being given function of the deadlines met and quantities set out.

In the situation in which the corporation wishes to stay in the market, even though a strategic unit is in decline, replacement of a part of the personnel becomes important. In order to dismiss some of the older employees and replace them with others better suited for the circumstances, assessment becomes especially important. It is recommended for the competent employees to be stimulated to stay. Selection should be done in such a way as to bring in 'fresh blood', which might contribute to recovery. If the survival strategy has in view entering new markets, personnel training becomes vital, because the staff should become familiar with the new products and services.

#### 4. Structuring human resources functions

If making organizational structure definitive is one the ways in which the organization strategy should be implemented, restructuring human resources function is the prerequisite of the success of human resources strategy, by correctly connecting the related activities to the environment of the organization.

The structure of the human resources function depends, as it has been shown, on the organizations dimensions. If in small organizations the activity is limited to recruitment – selection, dismissal, training and compensation, being able to be covered by the director or one single specialist, the range of services increases with the size of the enterprise.

The concept of ‘human resources management’ differ from the concept of ‘personnel management’, by the number and complexity of activities. The first includes planning, career management, social dialogue, benefits given to employees (medical services, meals). These activities are under the guidance of human resources specialists, coordinated by a head of service or a director, who reports either to the general director or to a deputy director, usually the administrative one. In large corporations, with complex activities, the service is divided in offices, their personnel being well specialized in a certain activity. Moreover, departments of human resources can be organized in the strategic units of the corporation.

The activity of human resources managers has a serious interactive character; therefore they should have, besides a high level of competency, certain additional qualities, namely:

- Negotiation aptitudes;
- Influencing power;
- Talent to be made respected, sympathized, and to earn the trust of the general director and the management team;
- Strategic thinking, with the help of which to develop human resources strategies at corporate, managerial and operational level;
- Capacity of counseling the general director, of influencing him/her and the top managers and of entailing them in solving problems related to human resources;
- Talent of noticing and indicating when the modification of the organization’s culture becomes necessary and of creating new practices to ensure personnel and socialize;
- Capacity of continually perfecting the informational system, by using the process of personnel assessment, publications, internet, organizational communication;
- Capacity of developing public relations activity;
- Capacity of using strategically the activities of human resources created, emphasizing the benefits they bring to the organization, thus obtaining a greater influence of the human resources department in the decisional process.

#### 5. The role of the human resources manager in the organization

In the last years, it is considered that the activities of the specialists in human resources can fall into four large categories:

1) *Initiation and formulation of policies*. These are meant to solve the problems existing in the organization or to anticipate the occurrence of others.

2) *Consultancy*. The human resources specialists are required to have knowledge on and give advice regarding: labour legislation, practices in the branch and in the economy, experience in the respective domain, practices in the field of branch and economy, experience in the respective field, requirements of the organization and employees, possibilities of their harmonization.

3) *Service*. They will have to coordinate the activities of recruitment, selection, assessment, career management, employees’ training.

4) *Control*. They also have to monitor the performances carried out in the operational and functional compartments to ensure that their activities would be aligned to the established policies, procedures, and practices.

Although all the four attributions of the specialist in human resources listed above are extremely important, the most important is that of counsellor in the organization. He has the task of identifying the best ways to harmonize people, jobs, organization and environment, counselling the managers and the directors in this sense.

Exerting the role of consultant involves earning the trust of the managers by competencies and experience accumulated in years. Counselling given to managers by the specialist of human resources consists of identification and solving problems they have relating the personnel with which they work.

Among the managers and specialists in human resources there is a relationship of cooperation involving several stages to be covered:

1) Identification of negative symptoms related to an employee or a group of employees. Usually, this is noticed by the operational manager, who has in is in charge of the employees and who has the closest relations with them.

2) Diagnosis. The human resources specialist identifies the problems and their causes, collecting information on the employees, jobs, organization and environment, using methods like: observation, documentation and interview.

3) Planning. The human resources specialist establishes measures by which the problem will be solved, including revision of policies and practices.

4) Implementation. This stage implies conjugated efforts from the part of the human resources specialist and the directly involved manager.

5) Follow-up. The domains where initially the negative symptoms have been noticed are examined, assessing the improvements obtained.

Consequently, the human resources manager advises the managers in various structural links of the organization what measures should be taken, to solve certain personnel related problems, how to implement those and how to follow them up.

One shouldn't forget his/her major responsibilities regarding: recruitment; selection; orientation; training; performances assessment and recommendations on salary increase, promotions or transfers; draw up career management programs and labour protection.

## 6. Human resources' function assessment

Many of the specialists in the field of human resources consider that the results of his/her activity cannot be quantified (for example, increase of work satisfaction, or greater opportunities for career development) and the financial contribution of the human resources function to the improvement of the enterprise activity cannot be established. Therefore, general directors are not always aware of the importance of this position, and cut down the budgets of human resources whenever the slightest financial problem comes up, although they declare that personnel is the most important resources of the organisation. In many organizations there are no available financial resources for important activities, such as job analysis, assessment of training activity or the use of more complex methods of employees' selection.

Generally, human resources are seen as cost generating activity, without directly contributing to the incomes of the enterprise. Therefore, it is often in the focus of expenses reduction. Considering the costs and benefits, human resources activities are classified by the directors and managers in; essential activities, optional activities, optional studies.

*Essential human resources activities* are those, in their view, without which the organization cannot develop. The need for these activities is decisive and real, although they involve high costs, and the benefits of these activities are direct and measurable. Such activities are: recruitment, selection, training at the workplace, salaries, benefit programs, labour protection, and relations with the Unions.

Recruitment-selection programs provide the necessary employees for the organization, with adequate qualities for the respective jobs. Training programs at the workplace provides accomplishment of the necessary performances standards. Programs ensuring compliance with the government regulations, contribute to avoid legal expenses. Good relations with the Unions, and the success of salaries and benefits negotiations with the Unions contribute to avoiding strikes and related expenses. Optional human resources activities are considered: job analysis, performances assessment, career development, training programs, organizational communication, human resources planning.

Managers believe that those are useful management instruments, but costly, and without a clear and immediate usefulness for an organization. Since the benefits of these activities are considered indirect and unquantifiable, in certain organizations they are treated as being unimportant, in others they are treated as a luxury possible to be satisfied only in favourable economic conditions.

*Optional studies* of human resources such as:

- survey for analysis of employees' attitude;
- assessment of personnel training programs are the least admitted as being necessary by the managers, who rarely understand their usefulness, which is difficult to be quantified.

It has been previously shown that the human resources managers' power of influence depends on their competency and qualities, especially that they have no direct decisional power. In order to obtain the required funds for the human resources activities, they have to find economic justifications to demonstrate their effectiveness.

To this end, they can use the cost-benefits model of assessment of human resources program. This has four components: 1) efficiency model, 2) economic model, 3) cost benefits comparison and 4) decision to continue, repeat, or change the training program.

1) *Efficiency model* is quite often used (for example, when training programs or employees' attitudes are assessed). It has five stages:

1.1) *Analysis of the program's necessity* emphasizes the problems it has to solve, and allows comparison between the situation of the enterprise before and after the program. In the case in which the identified problems in this stage are not gone by the end of the program, it means that it did not have the expected success. In the analysis of the necessity of the program, one starts from the identification of symptoms; this puts in the limelight the lack of correlation between employees, jobs, organization and environment. In order to be able to better evaluate the changes occurring as a result of the program, it is useful to measure as many symptoms as possible, such as personnel fluctuations, absenteeism, work productivity, overtime etc.

1.2) *Planning the program* means choosing the most adequate alternatives, meant to improve the relations between employees, jobs and organization. Irrespective of the variant selected, the program efficiency assessment methods should also be set out, as well as the ways the human resources manager and the interested managers can be involved.

1.3) *Quality assessment* of the way in which the program is implemented involves:

- follow-up of the activities in their succession;

- data collecting and processing, according to the established program;
- identification of the deviations from the program or the imperfections of the designed program;
- information on how the program is covered.

1.4) *Quantification of the program effects on the perceptions and attitudes of the employees*, if the perceptions and attitudes of the employees are not changed, it means that the program was not well designed and covered.

1.5) *Measuring the program effects on the changing of the employees' behaviour*, for example work productivity, quality of the activity covered, absenteeism, fluctuation, occupational accidents, complains, medical leaves.

Each of the five stages offers important information regarding the causes of the success or failure of the program.

2) *Economic model* transposes the respective human resources program in the language of the decision-makers of the organization, namely the economic ones. They want to know the investments the program involves, on the one hand, and the value of its effects, on the other. When in the human resources department, the economic effects of the expenses with the respective program cannot be calculated, which happens quite often, the top managers naturally cut down the human resources activities related budget. Therefore, a competent human resources manager should be capable to calculate the economic costs of the program, and also the economic effects, namely the additional incomes and/or reduction of expenses obtained as a result of the improvement of indicators, such as: absenteeism, delays, fluctuation, strikes, plans accomplished in due time, quality of activities, occupational accidents, accidental repairs, use of materials and stock reduction.

3) *Costs-benefits comparison* should lead to the conclusion that the latter are superior. Otherwise the program is not justified.

4) *The decision to continue, repeat or even change* the program involves four stages to be covered:

4.1) Description of all the programs alternatives (in operation or proposed), depending on the objectives, program costs and benefits.

4.2) Separate the human resources programs imposed by the legislation from the optional ones.

4.3) Feasibility assessment of each program according to criteria such as: complexity, qualified personnel in the human resources department or consultants' department, easy implementation, net economic benefits, risks.

4.4) Programs hierarchy in order of their necessity, the first being those required by legislation, which are allied irrespective of their efficiency. Optional programs are put in the hierarchy, according to the easy or difficult implementation, and their expected economic effects.

## 7. Conclusions

In conclusion, we can say that in conditions of increased competitiveness, the organizations will spend large amounts of money only for human resources programs, with clear costs and value benefits as a result of which the benefits are higher than the costs.

## References

Ciobanu Ion, *Management strategic*, Editura Polirom, Iași, 1998

Dumitrescu M., *Strategii și management strategic*, Editura Economică, București, 2002

Istocescu A., *Strategia și managementul strategic al organizației - Concepte fundamentale/ Aplicații manageriale*, Editura ASE, București, 2005

Mintzberg Henry, Ahlstrand Bruce and Lampel Joseph, *Strategy Safari. A Guided Tour Through The Wilds of Strategic Management*. Free Press, 2005

Neamțu L., Neamțu A., *Management strategic - principiile succesului*, Editura Academica Brâncuși, Tg-Jiu, 2009

Popa I., *Management strategic*, Editura Economică, București, 2008



## Discrepancies identified at an organizational level between managers and employees

Maria Magdalena Criveanu<sup>a</sup>

<sup>a</sup>University of Craiova, Alexandru Ioan Cuza 13 Street, Craiova, 200585, Romania

---

### Abstract

One of the major concerns of today's management is the harmonization of employee-management relationships. It is a known fact that one of the main sources of conflict at the organizational level is the discrepancy between the employees' expectations and those of the managerial staff. Thus, managers are increasingly involved in the relationship with the staff, wanting to identify possible inconsistencies, in order to prevent conflicts. As a consequence, the present paper aims at providing managers with an organizational analysis model in order to identify possible discrepancies between higher and lower hierarchical levels, in terms of organizational culture. In order to come up with the diagnosis in what the organization is concerned, we have used in our research a tool for assessing the organizational culture, which records the choices that the members of the organization have made. The data is then processed by bearing in mind the two categories, which are employees / managers, then interpreted according to the scale of points assigned to each organizational dimension. This will give us a dual representation of the organizational culture for the two categories, namely, employees and managers. The end of the paper provides with an assessment of these data, giving solutions to improve or even suppress these discrepancies.

*Keywords:* organizational culture, leadership, organizational conflict, managers.

---

### 1. Introduction

In the context of a labour force crisis, triggered mainly by the employee migration from the private sector to the state sector as a consequence of some favourable actual regulations of this sector, the managers are striving to develop a series of tools meant to offer an explanation regarding the employees' lack of satisfaction with the private sector. Of course, one of these complaints are related to the organizational conflicts, which are usually generated by the cultural discrepancies between the employees and the leaders. In this respect, we have analyzed the dimension *Organizational leadership* within a private company from Craiova whose main area of activity is the distribution. Thus, the people who were involved in this study have answered a series of questionnaires that evaluate the organizational culture by mentioning both the actual state within the company, but also the state they aim at. The questionnaires have been divided into two categories of wage earners, managers and employees, and the results have also been interpreted in a different way by bearing in mind this division. In this way, we were able to analyze both the discrepancies between what the employees regard as being valid in what the leaders are concerned, but also the situation they strive for, which means the path that the members of the management could follow, but also the board's opinion regarding the actual leadership and the one they want to achieve. In this respect, we have used a tool in order to evaluate the organizational culture (Organizational Culture Assessment Instrument - OCAI), which belongs to the two specialists, Kim Cameron and Robert E. Quinn, who have identified the 6 dimensions one should approach when shaping a full cultural profile. The 6 dimensions refer to: Dominant Characteristics, Organizational Leadership, Management of Employees, Organization Glue, Strategic Emphases, Criteria of Success.

The first part of the study aims at identifying a cultural type in what the dimension *Organizational leadership* is concerned. This dimension is analyzed both from the employees' perspective, as well as reflecting the status of the individuals who have a leading position. The role of this division into two wage earner categories, managers/employees, is that of pointing out some potential inconsistencies between what the employees regard as being something dominant within the organization and what the managers think the specific culture is. The leading style is a specific element, because the leadership is increasingly significant when it comes to organizing the activity of the private companies. This study has counted with the answers of 50 subjects, out of which 12 have signaled that they have a leading position within the enterprise, whereas the rest has rendered itself as normal employees.

## 2. The hypotheses of the scientific research

Throughout this study we have borne in mind also the validation/ invalidation of the following scientific hypotheses:

**Hypothesis no. 1:** When it comes to the dimension *organizational leadership*, there is a conflict between the employees and the managers, because the two categories of subjects tend to identify two different types of culture for this dimension.

**Hypothesis no. 2:** The culture identified by the employees will be the market type one, whereas the culture pointed out by the managers will be the clan oriented one.

**Hypothesis no. 3:** The employees strive for a clan oriented culture, a human resources oriented culture, thus claiming that they need the managers' attention.

**Hypothesis no. 4:** The managers aim at a hierarchy oriented culture because they assume that the more strict, formal and organized environment from the public sector is important for the personnel's stability and therefore that the harsher rules forestall the migration from the public sector towards the private one.

## 3. The Dimension of the Organizational Leadership viewed from the managers' perspective:

Before starting to analyze the results that we have come up with, we will briefly describe the 4 types of culture, i.e. the clan oriented culture, the hierarchy oriented culture, the market culture and the adhocracy oriented culture.

The clan oriented culture: The leaders are seen as mentors or even as fatherlike figures.

The market culture: The leaders are regarded as being strong, productive and competitive managers. The managers are firm and strict.

The hierarchy oriented culture: The leaders are perceived as being good coordinators and organizers, efficiency oriented. Their purpose is that of maintaining the organization at a constant level.

The adhocracy oriented culture: the leaders are innovative, willing to take risks.

The dimension *Organizational Leadership* stresses out how the organization's leaders are perceived, the way they behave towards their employees and which their perception regarding success is. By analyzing the results that we have come up with after having interpreted the questionnaires, there can be noticed that, the opinion of the subjects who are at a high hierarchical level, which means, they have leading positions, is that leaders are innovative and willing to take risks (the adhocracy oriented culture has registered 35.00 points). They are, at the same time, competitive, productive and good managers (the market culture has 30 points).

At a lower level, they are regarded as good coordinators and organizers (the hierarchy oriented culture has 20 points). At a lower scale, the leaders are regarded as being mentors or fatherlike figures (the clan oriented culture has 15 points). This points out that, for this dimension, the discrepancies between the wanted culture and the actual one don't register higher differences than 10 points or even this value, thus this does not require an increased attention in any of the 4 situations. The clan oriented culture has registered a positive increase of 5 points, whereas the market culture has a decrease of 5 points. The adhocracy oriented culture and the hierarchy oriented culture have registered no changes. (as you see in figure no.1).

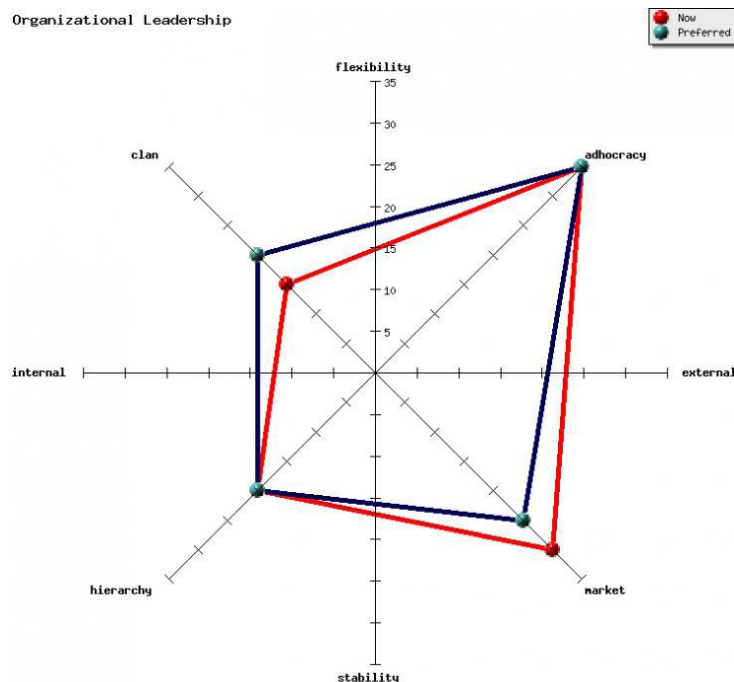


Fig.1. Organizational Leadership Dimension viewed from the managers' perspective

#### 4. The Dimension of the Organizational Leadership viewed from the employees' perspective:

By analyzing the same dimension, but from the employees' perspective, there is a different situation in what the identified type of culture is concerned. The employees regard the leaders as being strong, productive and competitive, but, at the same time, also as being firm and strict (the market culture has the highest score - 50 points). When referring to the wanted situation, there is a significant difference regarding this type of culture, which means a decrease of 30 points, a wish to improve, even to supersede these features. Such a difference points to a way too high disparity between what the employees experience as being the actual organizational climate and what they really want. The adhocracy oriented culture has 30 points, and not 35 points as in the managers' perception, the latter ones have also mentioned features such as creativity and willing to take risks. Also in this case there is a tendency of improving this predisposition, sometimes the risk is considered to be a threat against the employee and the job reliability. The hierarchy oriented culture has only 15 points and thus the concepts of stability, reliability, of being something permanent do not shape the leader's profile, whereas the clan oriented culture is almost invisible. At this level also there is a difference of 45 points between the actual and the wanted state, a difference that urgently requires the managers' interference because it is an obvious source of conflict.

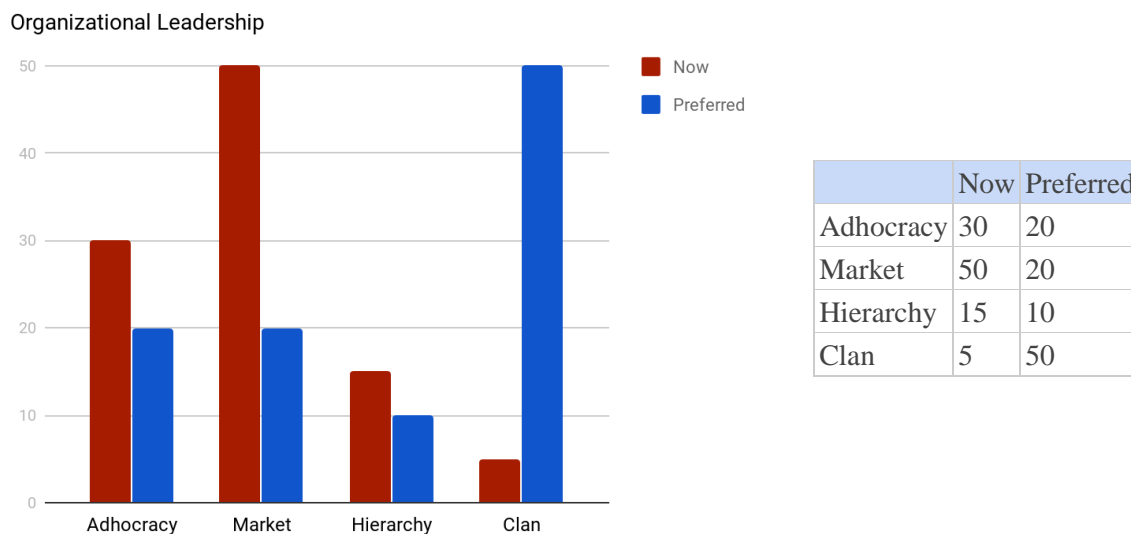


Fig.2. The Organizational Leadership Dimension viewed from the employees' perspective

#### 5. The validation of the hypotheses of the scientific research

**Hypothesis no. 1** is totally valid, the two categories of wage earners have different visions regarding the leaders' behaviour. Hence, if, in the employees' opinion, the leaders appear as being firm and strict, (the market culture is the dominant one) they will consider themselves rather as being innovative and willing to take risks (the adhocracy oriented culture mainly shapes the leader's profile).

**Hypothesis no. 2** is partially valid, the employees render the market culture as the dominant one, but the managers accept the low interest towards the human resources or towards the creation of a familiar environment, by rather stressing out a competitive climate.

**Hypothesis no. 3** is totally valid, the employees claiming that they need an increased attention from their managers, who, being dominated by a high trade sense, ignore the significance of the human resource and become the prey of the desire to make profit.

**Hypothesis no. 4** is not valid, therefore there are no significant discrepancies between the actual situation and the one the managers strive for. The adhocracy oriented culture has not registered any changes and it is still considered to be the best attitude the managers could have.

#### 6. Conclusions and recommendations

As a conclusion, with the help of this analysis we have identified the existence of a conflict within the organization, a significant unease pointed out by the employees, but also some disparities between the perspectives of the two categories (employees and managers). Hence what can be noticed is that the actual situation within the enterprise is perceived differently by the higher hierarchical levels, where the managers render themselves as innovative, autocrat, ambitious, whereas the lower hierarchical levels regard them as firm and strict. But the most important source of conflict is not the actual situation, but the situation the enterprise is striving for. If, from the leader's perspective, the situation is accepted, tolerated and even still wanted, the differences between the two states being insignificant, things are different from the employees' perspective. Not only they identify a different type of culture, but the major source of conflict is the dissatisfaction degree with the actual situation. The employees reprobate the authoritarian leading style,

whose main purpose is the profit, the clients and requires an increased attention in what the employees' needs are concerned. Taking this into consideration, it is recommended that the managers notice these disparities and take into account the employees' perspectives, especially when confronted with such a labour force crisis. Because the public sector offers its employees a series of indisputable advantages, such as the job reliability, continuity, a stable schedule, stability and even motivating incomes, the statistics showing that the incomes from the public sector are higher than the ones in the private sector, a change of attitude and perspective is required in order to annihilate or, at least, to improve these negative aspects. Probably one of the aspects that the public sector does not take into consideration refers precisely to the close attitude between the employees or to the familiar environment which is not specific to state institutions. This aspect must be speculated on by the private environment that can compensate these disadvantages by showing an increased interest and attention in what the employee is concerned.

Taking this into account, the manager who is supposed to make the change must have as the center of his preoccupations the human resource and therefore to identify its needs and potential ways of complying as efficient as possible with the employees' requests. A lot of private companies gamble on the relationships between the co-workers established within the enterprise, but also on the relationships between the employee and the manager, because they act as a bond, as a connection between the employee and the enterprise, thus ensuring a sustainable and stable relationship. In this respect, the manager stands for communication, for solving conflicts through negotiation, for the cancellation of the borders between the higher and the lower hierarchical levels, for the team work, for the organization of social events which act as an integrating myth.

Hence, the first step takes place when the managers admit that there is a need for change, then try to implement the way the company is going to follow in order to achieve this change. A pertinent example refers to setting up team buildings, where the employees will acquire new skills or knowledge, where they have the possibility of knowing each other better, of creating social connections and of cooperating in order to solve some tasks, because team buildings are usually organized based on common activities. Another significant aspect is connected to identifying a leader for these activities who manages to make the teamwork and encourage it, thus contributing to the annihilation of the borders between leaders and employees because when it comes to such activities the leader status is gained through the presence of a series of indisputable capacities and not through the stiff higher position within the organizational chart.

What counts as another important aspect can be the increased attention shown to the signs and symbols, the rituals and the myths, that contributes to the shaping of an inner and outer organizational identity. The employees end up accepting these elements as their own and will form a powerful culture, which will prevent the surfacing of certain negative phenomena such as the migration and will cause the group to fall apart. The participatory management contributes to the annihilation of the differences between the two categories of wage earners, therefore making decisions together is a good way to involve the personnel in the company's activity, to offer them attention trust and even to provide them with a series of responsibilities.

At the same time, managers refuse to invest in the human capital any longer, because they regard the investment as useless when the employees leave the company and the possibility to recover the lost investment is basically non-existent because of the increasingly higher personnel mobility. On the contrary, such investments increase the degree of involvement the employee has, because he achieves new knowledge and it becomes more productive, and the investment is regarded as a way of agreeing with his skills, but also as a proof of the increased attention whose beneficiary the employee is, which is exactly what they claim as being necessary in order to improve the cooperation.

Changing the organizational culture will also imply benefic effects in what the whole activity is concerned, thus annihilating a series of negative effects such as absenteeism, not being willing to work overtime when necessary, but also the improvement of the efficiency and efficaciousness through involvement.

## References:

- Burduș, E., Căprărescu Gh., Androniceanu A., Miles M., *Managementul Schimbării Organizatională*, Editura Economică, București, (2000).
- Cameron, Kim S., Quinn Robert E., *Diagnosing and changing organizational culture-Based on the Competing Values Framework*, Jossey-Bass, A Wiley Imprint, (2011).
- Cameron, Kim S., *Downsizing, Quality, and Performance*. In Robert E.Cole (ed.), *The Fall and Rise of the American Quality Movement*, New York, Oxford University Press, (1995).
- Cameron, Kim S., *Techniques for Making Organizations Effective: Some Popular Approches*. In Daniel Druckman, Jerome E.Singer, and Harold Van Cott(eds.), *Enhancing Organizational Performance*.Washington, D.C.:National Academies Press, (1997).
- Colquitt, J., Lepine, J.A., Wesson, M.J., *Organizational behavior:Essentials for improving and commitment*, Boston: McGraw-Hill Irwin, (2010).
- Gordon, G. G., *The Relationship Between Corporate Culture and industry Sector and Corporate Performances*. In Ralph H., Kilmann and Associates, *gaining Control of the Corporate Culture*, San Francisco: Jossey-Bass, (1985).

## Advances in Occupational Ergonomics and Risk Management

Sabina Irimie<sup>a\*</sup>, Adrian Lucian Pal<sup>a</sup>

<sup>a</sup>University of Petrosani, Universitatii street, No. 20, Petrosani, 332006, Hunedoara

---

### Abstract

Quality of life in the workplace implies the well-being of employees. Lately, the expression "happy employees" has become more and more common and it is a concern of the inseparable relationship between employers and employees. This paper aims to present a new model of ergonomic risk assessment in the field of automotive industry, field with a significant weight in Romania. The challenges of such an industrial branch in terms of designing the workspace or setting it up are significant, because in many companies at national level there are no specialists to assess the worker and the place where he performs the work task, based on the concept of security process and rules, and the ergonomic aspects of the workplace.

The goal of this paper is to sensitize specialists who, in the future, using the results of an assessment of the ergonomic risks on which is subjected the worker from the assembly line/rubber processing machine operator in the automotive industry, can be identified the level of risk associated with aspects of this industrial area and measures to improve the workplace can be proposed to increase productivity and eliminate or minimize present risks.

Keywords: occupational ergonomics, ergonomics risk, risk management

---

### 1. Introduction

Wellbeing at work, which is one of the world's main concern in terms of both occupational safety and health and ergonomics, and has consequences both at the organizational, individual and ultimate levels of society. This aspect was also highlighted by the 7th International Ergonomics Conference ERGONOMICS 2018 from Zadar, Croatia, which took place in June 13-16, 2018 under the title "Emphasis on Wellbeing".

Many specialists (Felce and Perry, 1995; Danna and Griffin, 1999; Diener, 2000; Waddell and Burton, 2006) defined well-being as the subjective state of being healthy, happy, contented, comfortable and satisfied with one's quality of life. It includes physical, material, social, emotional ('happiness'), and development & activity dimensions.

Recent global approaches reflect these concerns by focusing on integrating occupational safety and health and ergonomics into applications and models for improving the quality of work, designing or creating a healthy workplace and eliminating or minimizing the risks associated with exposures to the poor working environment, the non-economic working conditions and the psychosocial, psychosomatic, cognitive environment, etc., concerns that once neglected inevitably lead not only to deficiencies in the production rhythm but also to the occurrence of musculoskeletal disturbances or disorders. All this results in economic and social losses.

In Romania there is no national legislative basis for the development of workplace wellbeing activities or a model established among communities in the field of public health, safety and health at work. The concept is known only by occupational health and safety and human resources specialists. There are different work patterns applied differently in some companies (health education - collective sessions, health education - individual counseling, fitness center, etc.). Also, the profession of ergonomist appeared only in 2017. (Irimie et al., 2017; Boatca et al., 2018)

Experts Anttonen and Räsänen (2008), Härmäläinen (2007) knowing that one of the common goals ergonomics and safety and health is well-being, have analyzed at European level if the legislation mentions this concept and if it is implemented. The results of the study are presented in Table 1.

---

\* Corresponding author. Tel.: +40723718829  
E-mail address: sabina.irimie@gmail.com

Table 1. Legislation and implementation of W-BW strategy and models in partner countries

Country	Concept mentioned in legislation?	Idea implemented on country level	Implemented on enterprise level
Belgium	yes	yes	yes
Finland	yes	yes	yes
Germany	yes	yes	yes
Ireland	no	yes	yes
Italy	no	no	yes
Romania	no	no	yes

Source: Anttonen & Räsänen, (Eds.), 2008, p.14.

The main ergonomically specific risks, the working situations from the assembly lines characteristic of the automotive industry and a new assessment method are presented below.

## 2. Ergonomic risk assessment

“In line with the EU Strategic Framework on Safety and Health at Work 2014-2020, one of EU-OSHA’s priorities is to support the prevention of work-related diseases. The aim is not only to improve the lives of individual workers, but also to minimize the costs of work-related illnesses and deaths.

The number of workplace accidents has decreased by 25% over the last 10 years. However, work-related diseases still account for an estimated 2.4 million deaths worldwide each year, 200,000 of which are in Europe.” (EU-OSHA, 2018) According to the observational epidemiological study program worldwide Global Burden of Disease Study (GBD) 2010, work-related musculoskeletal disorders are the second major cause of global disability and have risen by 45% worldwide, being considered the main cause of pain and long-term disability in the world, (Byl et al., 2016). Since then, in all reports of the EU-OSH, musculoskeletal disorders are still the first and the automotive industry has many jobs with such risks. (EU-OSHA, 2010)

In Middlesworth's view, risk factors are grouped into two categories, ergonomic risk factors and workplace specific risk factors. Extensive exposure to ergonomic and individual risk factors leads to musculoskeletal disturbances or disorders. (Figure 1) We can also mention ergonomic risk factors lack of education in this field, which also determines the manifestation of individual risk factors.

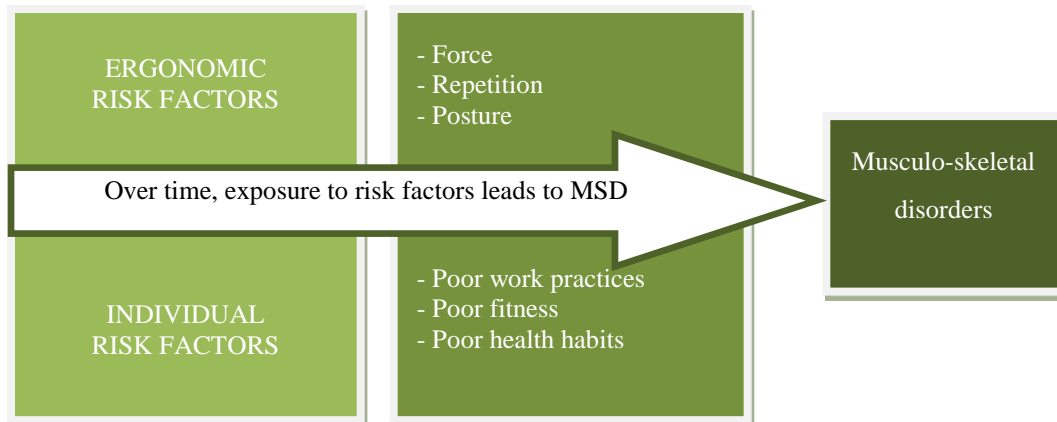


Fig. 1. Risk factors that lead over time to musculoskeletal disorders

Source: Middlesworth, M. (<http://ergo-plus.com/musculoskeletal-disorders-msd/>)

In the specialty literature it is recommended that the risk management process be integrated and adapted to the culture, practice and organizational activity. (Figure 2)

Figure 2 exposes from the perspective of risk management, the logic schema of the risk management process, and figure 3 presents the logical schema of the risk management process from an ergonomic perspective.

In terms of risk assessment, this is defined as "activity identifying risk factors for injury and/or occupational disease and quantifying the level of risk of a workplace/workstation." (Mohanu, 2015)

In order to identify the ergonomic risks on which rubber processing machine operator in the automotive industry is subjected, an ergonomic risk assessment model was used, proposed by the University of Washington Ergonomics Laboratory, Department of Environmental and Occupational Health Sciences of the School of Public Health.

There are two approaches to initiating an ergonomic risk assessment: proactive and reactive. In order to implement an ergonomic risk assessment, there is a need for coordination and teamwork, aspects that ensure that the evaluation process is carried out in a systematic manner. (Department of occupational safety and health ministry of human resources Malaysia, 2017)

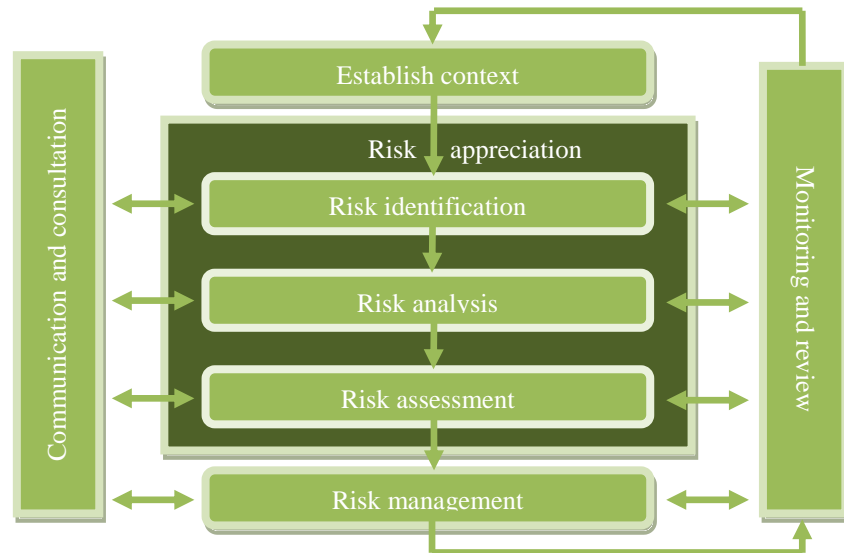


Fig. 2. Risk management process  
Source: Moraru, 2017, p. 10

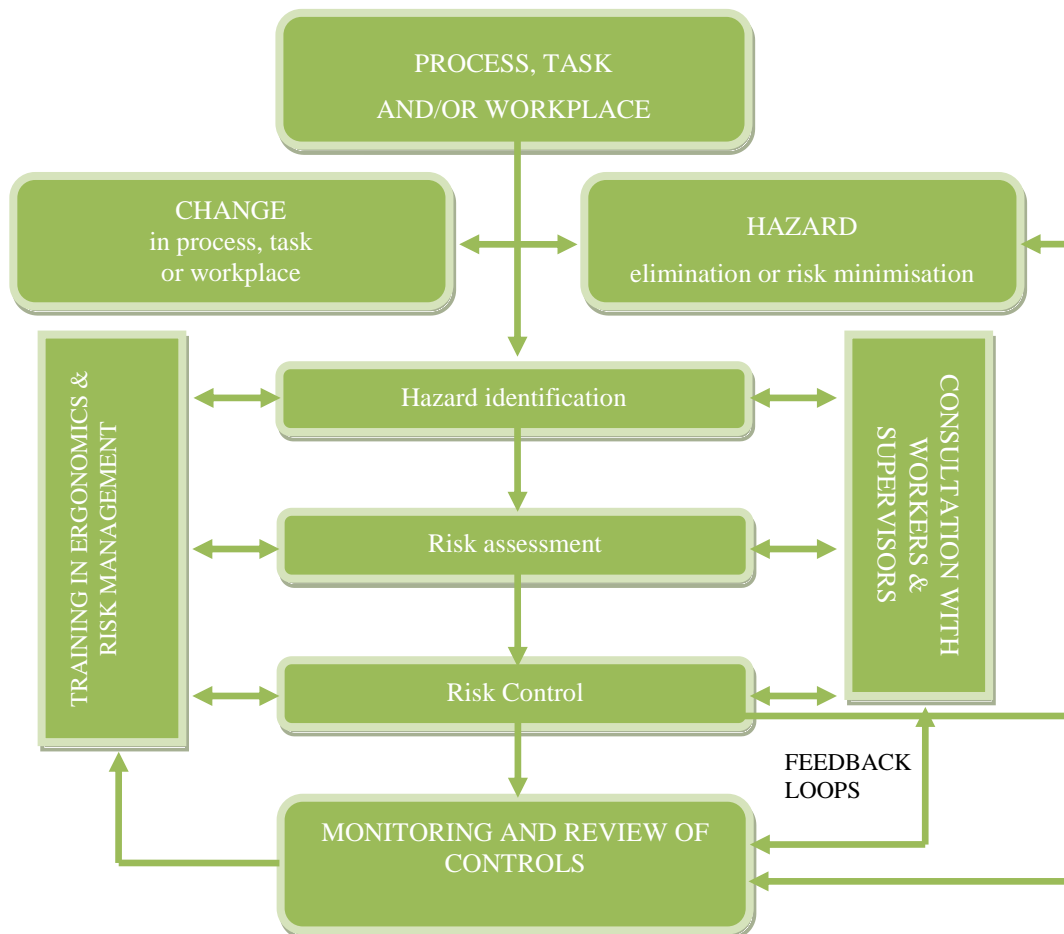


Fig. 3. Ergonomic risk management process  
Source: Scott, P., Kogi, K., McPhee, B., 2010, p. 37

Person responsible for leading the evaluation team must be a trained person, a person in charge of the overall evaluation management. In order to prepare an ergonomic risk assessment, consideration should be given to team training, tools, materials and facilities, communication and coordination.

Initial ergonomic risk assessment sheet (table 2) is a dated and assumed document developed at the ergonomic risk assessment initiation stage addressing the aforementioned issues as well as risk factors reported through the proactive approach inspection.



Table 2. Initial ergonomic risk assessment sheet

<b>Task:</b> Tire manufacture		<b>Task description:</b> The rubber once manufactured reaches the “Building / Confections” location, where it is processed using machines in different sizes, depending on the manufacturing process stage. The tire maker, in the first stage of the manufacturing process, uses a three-layer folding machine (tire strap) on the inner skeleton of the tire. The worker must always ensure that the machine is operating at normal operating conditions, take measurements to ensure that there are no deviations from dimensions or gaps, ensure that the machine is continuously fed with rollers containing thin rubber strips, textile strips and metal strips. The task is completed when the tire, at this stage, is sent on the line to the next worker. The worker performs the work load alternating between the orthostatic position and the sitting position. In order to carry out the work load the worker uses his hands in most cases.	
<b>Location:</b> Building/Confections			
<b>Assessment team:</b> (Names of all participants)			
<b>Date:</b> 15.01.2018			
<b>Risk factor</b>	<b>Action items :</b>	<b>Assigned to</b>	<b>Revised</b>
<ul style="list-style-type: none"> <li>- The back is twisted and bent sometimes;</li> <li>- Working with the hands at a lower angle than 90°;</li> <li>- Almost continuous movement of the arm;</li> <li>- Working with the wrist bent;</li> <li>- Working with the head bent;</li> <li>- Working bank not adapted to the anthropometric dimension of the worker;</li> <li>- The seat cannot be adjusted to the anthropometric dimension of the worker.</li> </ul>	<ul style="list-style-type: none"> <li>- Observer’s assessment sheet;</li> <li>- Worker’s assessment sheet;</li> <li>- Exposure scores sheet;</li> <li>- Risk assessment matrix;</li> <li>- Guide for handling the weights;</li> <li>- Guide for recommended weight limit for lifting and lowering for repetitive operations;</li> <li>- Charts and interpreting tables.</li> </ul>	(Names and attributions of all participants)	<b>Back:</b>  <b>Shoulder/Arm:</b>  <b>Wrist/Hand:</b>  <b>Neck:</b>  <b>Stable base/Driving:</b>  <b>Vibration:</b>  <b>Work pace:</b>  <b>Environment:</b>
<b>Reviewed by:</b> (Location Manager)		<b>Approved by:</b> (OSH Manager)	16.01.2018
	16.01.2018		16.01.2018

Source: adapted from <http://depts.washington.edu/wineryhs/Resources.html>

As can be seen in the initial ergonomic risk assessment sheet, the first instruments of action used are the evaluation and the exposure scores sheets. Two of them are used for the evaluation, one for the observer's assessment, and the second for the worker's assessment.

The observer's assessment sheet is structured into five sections for each section, selecting only one of the associated situations, situations that concern aspects related to the following body areas of the worker: back, shoulder/arm, wrist/hand and neck.

The worker's assessment sheet is structured on eight sections, just like the observer's assessment sheet, selecting only one of the associated situations. In this case, it should be noted that the “environment” that is spoken in Section Q, in fact, means the stressors specific to the organizational environment (temperature, lighting, noise, etc.).

The scores obtained through the assessment made using the evaluation sheets and the exposure score sheets should be used for:

- Determination of the comparative exposure levels for each body area;
- Identification of the areas where the exposures are highest and concentration of interventions on such areas.

Assessment of the observer and worker, respectively the calculation of the exposure scores, for the situation of the operator in the rubber processing is presented below.

After the exposure scores have been calculated, the next step in the ergonomic risk assessment is the identification of the ergonomic risk level for each section using the risk assessment matrix (Table 3).

Following the interpretation of the scores obtained in table 3, for the first four sections, a low risk level was obtained for the “back” and “wrist/hand”, and for the “shoulder/arm” and “neck” the risk level is moderate. In order to better observe the classification of the scores obtained in the risk levels, the following four graphs were made for the first four sections (Figure 4).



Table 3. Risk assessment matrix

Risk assessment	Low	Moderate	High	Very high
	Evaluation scores			
<b>Back</b>	10-20	21-30	31-40	41-56
<b>Shoulder/Arm</b>	10-20	21-30	31-40	41-56
<b>Wrist/Hand</b>	10-20	21-30	31-40	41-56
<b>Neck</b>	2-6	7-10	11-14	15-18
<b>Stable base/Driving</b>	1	4	9	-
<b>Vibration</b>	1	4	9	-
<b>Work pace</b>	1	4	9	-
<b>Environment</b>	1	4	9	16

Source: adapted from <http://depts.washington.edu/wineryhs/Resources.html>

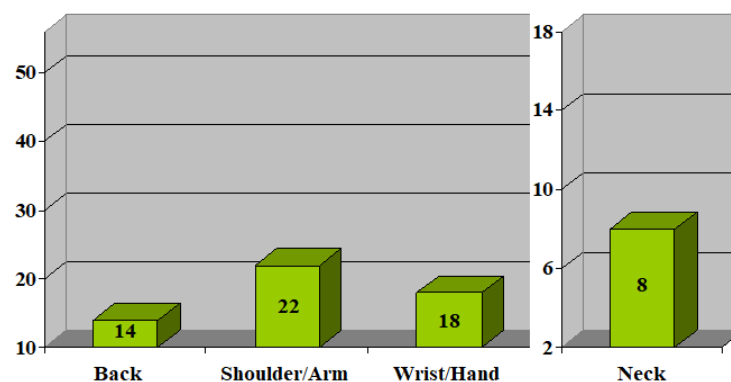


Fig. 4. Level of exposure scores for back, shoulder/arm, wrist/hand and neck

In the case of the last four sections, the level of risk obtained is low for “driving” and “vibrations”, and for “work pace” and “environment” the risk level is moderate. As for the first four sections, a graph was created for the last four (Figure 5) to observe the scores obtained in the risk range.

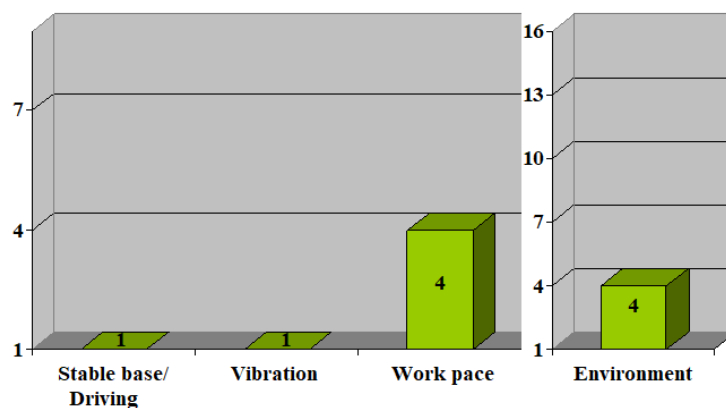


Fig. 5. Level of exposure scores for driving, vibration, working pace and environment

It can be seen from the interpretation of the scores obtained for each section, that the maximum ergonomic level at which the rubber processing machine operator is subjected on which this assessment was made is a moderate one.

It should be kept in mind that the moderate risk level with respect to the body parts of the worker is present at the shoulder/arm and neck, which confirms what was noted in the initial assessment sheet as a risk factor observed in the inspection carried out in order to initiate the assessment.

The “wrist/hand” section should not be neglected, even if the risk level is low in this case, the value of the scores obtained for this section is at the upper limit of the value range for this ergonomic risk level.

Compared to the “shoulder/arm”, “neck” and “wrist/hand” body parts, which could have been identified as ergonomic risk factors following the inspection to initiate the assessment, there are also issues that could not be identified as a result of this inspection. The “work pace” and “medium” sections with moderate risk levels can not be assessed in the initial phase by inspection, but only identified and interpreted by evaluating and calculating the scores obtained

## Conclusions

The conclusion is obvious, the need to increase the quality of wellbeing at work. Therefore, there are at least two major national challenges in this area. One of the challenges, since in most enterprises there are no ergonomic, health and safety professionals to carry out an assessment of the ergonomic risks associated with the workplace with a view to proposing and subsequently implementing the improvements for a job reduce or eliminate the risks associated with the industrial fields in which they operate, or instruct workers on exposure to such risks.

The second challenge is to improve legislation with ergonomics and well-being stipulations in organizing workplaces and companies, in general, to achieve the goal of "happy employees".

## References

- Anttonen, H., Räsänen, T., (Eds.), *Well-being at Work - New Innovations and Good Practices*, Finnish Institute of Occupational Health, Helsinki, Finland, (2008).
- Byl, N. N., Barbe, M. F., Dolan, C. B., Glass, G., Repetitive Stress Pathology: Soft Tissue, Chapter 27 In: D. J. Magee, J. E. Zachazewski, W.S. Quillen, R. C. Manske, *Pathology and Intervention in Musculoskeletal Rehabilitation* (Second Edition), Elsevier Inc., pp. 938-1004, (2016).
- Boatca, M. E., Irimie, S., Draghici, A., Ergonomics and occupational health and safety for wellbeing, *7th International Ergonomics Conference ERGONOMICS 2018*, pp. 73-80, Zadar, Croatia, (2018).
- Danna, K., Griffin, R.W., Health and well-being in the workplace: a review and synthesis of the literature, *Journal of Management*, 25, pp. 357-384, (1999).
- Department of occupational safety and health ministry of human resources Malaysia, Online from <http://www.dosh.gov.my/index.php/en/factory-machinery/guidelines/ergonomic/2621-01-guidelines-on-ergonomics-risk-assessment-at-workplace-2017/file>, pp. 10-11, (2017)
- Diener, E., Subjective well-being. The science of happiness and a proposal for a national index, *American Psychologist*, 55, pp. 34-43, (2000).
- EU-OSHA - European Agency for Safety and Health and Work, *OSH in figures: Work-related musculoskeletal disorders in the EU - Facts and figures*, Publications Office of the European Union, Luxembourg, (2010).
- EU-OSHA - European Agency for Safety and Health and Work, *Work-related diseases*, Online from <https://osha.europa.eu/en/themes/work-related-diseases>, 20 01 (2018).
- Felce, D., Perry, J., Quality of Life: Its Definition and Measurement, *Research in Developmental Disabilities*, 16, pp. 51-74, (1995).
- Hämäläinen, R-M., *Workplace Health Promotion in Europe - the role of national health policies and strategies*. Finnish Institute of Occupational Health, Helsinki. (2007).
- Irimie, S., Manolescu, A., Lupu, C., New perspectives of the relationship between occupational safety and health and ergonomics. Proceedings of the *8th edition International Symposium Occupational Health and Safety – SESAM 2017*, vol 1, pp. 268-277, Bucharest, Romania, (2017).
- Middlesworth, M., *The Definition and Causes of Musculoskeletal Disorders* (MSDs), Online from <http://ergo-plus.com/musculoskeletal-disorders-msd/>
- Mohanu, F., *How the risk assessment activity is carried out*, Online from <http://legislatiamuncii.manager.ro/a/18401/cum-se-desfasoara-activitatea-de-evalua-re-a-riscurilor.html>, April 24, (2015).
- Moraru, R., *Managementul riscurilor*, suport de curs, Universitatea din Petroșani, (2017).
- Waddell, G., Burton, K., *Is work good for your health and well-being?* The Stationery Office Publishing, London, UK. (2006).

## Minority in the Middle East: The Monotheists "Druze" in the Middle East, changes and competes

Mansour Radwan<sup>a,\*</sup>

<sup>a</sup> West Timisoara University- Romania

---

### Abstract

This article is intended to reflect on a comparative descriptive study the changes that have taken place in the community of the monotheists "Druze" throughout their history. Although this community was a relatively small minority living inside or outside a stronger majority and sometimes-hostile society to them, they continue to survive in contrast to the forces that acted against them, and did not assimilate into another population. The study examines phenomena in the monotheist "Druze" community. Some of their specialties and uniqueness, and includes the following fields : social changes over their history, the transition from a traditional society that lives in a closed circle to modern and semi-modern society, what remains and what has changed in its traditional society. Changes in the scope of marriage, the interaction between this community and the State of Israel over the years, social and historical aspects. Changes in education, in employment, in social and historical expressions of solidarity and social coherence among the monotheists "Druze" community. Religious customs, the monotheists "Druze" woman and her status in comparison with other communities. The monotheists "Druze" migration over history and its social implications in secularism. Religion, concept of the individual versus the collective, hatching in solidarity, grinding in status of clergymen, parents, and their crisis of identity. The purpose of this study is to point out and identify unique phenomena of this little community survival, to examine them over time and to compare them to other communities, to reflect on its status, to predict and point out its future directions.

*Keywords: monotheists "Druze"; modernization; women status in Druze society; religion; isolation.*

---

### 1. Introduction

The monotheists "Druze" lived in isolation on top of the mountains and kept the solidarity among themselves in various areas and among others in the Middle East. In this manner, the community existed as a special category, which has its own cultural, historic and ethnic basis distinguishing it from the Arabic and Jewish population. Although the monotheists "Druze" do not have a national state, they did manage to survive and keep an ethnic, religious, cultural and geographic uniqueness (Sofer, 1998 from Dana, 188-192). After the establishment of the state of Israel, the monotheists "Druze" chose to be part of the geopolitical-national entity. Although they are not part of the majority's nationality. On the other hand, they did not abandon their cultural legacy, did not assimilated and continue keeping religious isolationism and independence. The law of compulsory recruitment to the IDF was applied on them in 1956, and they were integrated in the Israeli security system. This recruitment deepens their differentiation and brought changes to the society of the monotheists "Druze. Even they have the Arabic as mother language like other minorities. (Halabi, 2009: 50). This change, push the modern world to find its way to the village's residents with new ideas that are strange to the monotheists "Druze", reduced to a higher education among this community's members (Hassan, 1992). Their localities began go through changes and urbanization and modernization processes, economic, occupational, physical and other changes in addition to geographic, political, social and religious changes. All those deepen the differentiation of the monotheists "Druze" and shaped specific category of their localities. But, simultaneously, kept the "selective modernization" model, in which they adopted new structures and values besides keeping the existing "traditional" systems in sort of instrumental functioning pattern. Their life in a social closed circle does not accept the other into society, marriage is internal endogamous, in the localities of the monotheists "Druze" and between localities in different areas. First, marriages were in the clan and between relatives. All land and assets were kept inside the relative's circles and strengthened the sense of belonging and solidarity between relatives and against external forces. The husband

---

\* Mansour Radwan. Tel.: +972506810631;  
E-mail address: radwanmans1@gmail.com

monotheist "Druze" calls his wife "My cousin" and it is not accidental. However, the phenomenon of relatives' marriage is common in many places in the world and is not necessarily unique to the monotheists "Druze" (Ladislav, 1989: 1).

Later, due to the clan's size and the localities' expansion, a distribution process started of concentrated building of the clans that brought a process of households' dismantling, economic independence and an individualization processes that is a part of global modernization. The marriage between clans strengthened blood ties, primordialism between clans and among the community members in localities. In addition, it created and strengthened large branched social networks of relatives on various levels of proximity. These connections strengthened the mutual guarantee and assistance, the solidarity, identification and sense of belonging within the community members in different areas. This is also not a unique phenomenon of the monotheists "Druze" and there are additional examples in the world (Osterreich, 1965:144). These blood ties who reside in a community in a close social circle, created an endogamous system of marriage, which strengthened members' solidarity. Furthermore, the sense of social bond, development of significant relationships and some even interpret it as blood brotherhood, (Brain, 1976). An additional process that took place in these localities was integrating immigrants, whole clans, immediate families and singles. In the 12th, 15th and 16th centuries, for example, lots of Druze immigrated from the Lebanon mountain, "Wadi a-teem" in southern Lebanon and Jabel Al-Aa'la in the Hallab area in Syria (Firro,1992:31-34).

This occurred as a result of an economic need and security reasons. Therefore, many Druze settled in Israel, specifically in the Upper and the Lower Galilee and in Carmel Mountain. The civil war in Lebanon in the 19th century encouraged an additional immigration, including the Maronites and the monotheists "Druze" that made entire clans follow even whole villages from the Lebanon Mountain to the Druze Mountain and to the land of Israel (Falah, 2000: 29-33). In the second half of the 20th century, many of the monotheists "Druze" from Syria and Lebanon searched for employment in Saudi Arabia and in the Persian Gulf countries. Others chose to immigrate to Europe, North and South America and to Australia (Saleh, 1989: 13). There were also immigrations to Canada, Brazil, Argentina, Venezuela, African countries, Western Europe, England, France and Germany (Halabi, 2009: 51-52). In Israel, by a multi-annual view, the number of students among the monotheist "Druze" increased within a decade and a half, between 2000 to 2015, to 2.98 times and almost tripled. Those that studied for a BA degree were 90% and 7.2% studied for a MA degree. Another change in 2010-2015 was an increase in the number of Master's degree graduates by 2.79 times (the CBS 2017/106). The generation that lived in the time of the establishment of the state of Israel showed loyalty to the state unconditionally and without reservation. However, the next generation was different as this was. This generation stopped being like the Jewish population and returned to reestablish and rebuild ethnic identity. This was like the transition stages described in the Helms model who researched the ethnic identity of black people in the United States (Helms, 1990). Unlike modern society, that leaves space in behavior norms and values related to life events including loss, it has no clear expectations; no clear and defined behavior rules and, it is in a state of lack of clarity (Granot, 1985: 90). The mourning customs fulfill the needs of the mourners and emphasize the intensity of solidarity from the community members' side. The relation of the monotheists "Druze" to death and mourning is special and different from other divine religious customs. For example, the body and life is treated as a transition phase. Life is described as a cloth which the soul wears and changes until its death (Talea', 2001:100). "Druze" believe in reincarnation, and the belief influences mourning customs and strengthens the internal solidarity and coherence among the community members.

## **2. Discussion of changes in the monotheists "Druze" minority society**

The belonging of the monotheists "Druze" as a persecuted religious minority strengthens the mutual guarantee and solidarity among its members. The structure and religion institutes of the monotheists "Druze" shows a firm grip of legacy, identity, culture, religious leaders and the social structure. This also includes harmony, consolidation and solidarity among members. The religious structure is first expressed in the pray house "AL-KHLWA", this is intended to be a place of being alone with the soul and far from daily affairs. It is also to review and read religious books and pray to God. The praying houses are quite modest, without any distinguishing marks or prominence. The religious books must be guarded zealously. Each locality of village has a praying house and sometimes there is more than one praying house. Sometimes, in a hostile environment and beside the praying houses of the monotheists "Druze" community, members built Mosques in order to survive and integrate in the Islamic environment and there was an unforgiving attitude towards being different (Al-Halabi, 2008: 47-48). In addition to the praying houses, the monotheists "Druze" have sanctity places, which are religious public buildings in places where a prophet passed, lived or an eminent religious person was buried. Almost in every locality of the monotheists, "Druze" there is a sanctity place (Al-Halabi, 2008: 45-48). In a social aspect, with mutual support and guarantee, alongside with the solidarity of the monotheists "Druze", independent public institutions were established and managed. These included associations, and maintained contact between the community members around the world. In Lebanon, the council of research and development (1977) was established as well as the religious council to repel slander and offensive publication of images. This council operated to conduct statistics, publish books and researches related to history, faith, customs and traditions of the monotheists "Druze".

The women from the monotheists "Druze" community had many roles in the agrarian society. Some of these included sewing and harvesting, and covered about 60% of a family's food source for many years. This was until the sixties of the 19th century. (Taki-A-Din, 2007: 30-33). A woman has a lofty status that entitles respect, appreciation and a special status in family and society. The woman is a central figure in the household and even has been defined as the beating heart of the house. The woman is responsible for raising and educating the children in the family and manages the house and the farm (Al-Halabi, 2008: 87). Note that the prohibition of polygamy in the monotheists "Druze" community is one of the woman's empowering expressions. Since the mid-20th century, there was a change in the monotheists "Druze" society and the process of immigrating from the intimate villages to larger cities began in order to find a suitable livelihood for families. The father moved temporarily and started working in the city. Later, these families settled after emigration, integrated in the new society. This caused a distance from the tradition, customs and values in which the families had been raised in the monotheists "Druze" community. Another change was the reduction and abandonment of the extended family and a focus on the immediate family. This means, that the individual had become a priority and thus began the process of individualization as practiced in contemporary liberalization in modern society (Taki A-din, 2007: 44-45). Overall, the social status of women in the monotheists "Druze" community is far superior to in comparison to other religions. This is due to the attitude of the monotheists "Druze" towards women. There are quite a few cases of women who have been at the center of social-religious activity (Taki A-Din, 2007: 39-42, 134 and on, Abu A'zz al-Din, 1990: 312-322).

### **3. Summary**

A visitor in the monotheists "Druze" villages sees a view of "white scarves like a group of pigeons arranged on the branches of a thick tree. Carrying scarves that hang from the head and wrap the shoulders and fall below the waist. There is refined clothing which are a pale color, these are clothes worn by an ascetic. It is a picture in which sincerity and spiritual beauty are deeply embedded, stemming from the pain of a soul that complements fate, surrenders to God's will and expresses both well-being and distress. It is a picture worthy of commemoration before it disappears from our memory" (Sa'eb from Dana, 1998: 199). Nowadays, when there is a semi ideological valuable vacuum and erosion of religious leadership, the white veil has slipped to the shoulders and sometimes even forgotten at home. The Symbolic White subtle colors have turned into a colorful, stylish and not modest look. Although there is spiritual beauty, there is physiological beauty and extravagant grace. The society of the monotheists "Druze" is in a transitional period from a being traditional which, used to be a patriarchal society, to a modern or semi-modern society without ideological anchors and without religious leadership. Thus, the secular moves towards secularism and nurtures one's intellectual and personal achievements. In addition, expands knowledge and education, wealth and assets, opens up to the world and constantly interacts with it. Moreover, asks questions of existential existence and identity, which do not necessarily have conclusive answers in intellectual sources. The life of the sons and daughters of the monotheists "Druze" in modern times is characterized by mental development, broad education, technological knowledge, improved quality of life, economic independence, and professional development of both men and women. On the other hand, it is possible to identify some distance from the original norms, customs, tradition and religion. These changes undermine social cohesion and identity formation among the younger generation in particular. The exclusivity of parents' education to the children has been severely impaired and the status as exclusive educators has been eroded in the face of environmental competitors.

### **4. Conclusions**

The status of the monotheists "Druze" community is in significant changes from traditional to modern class. This transition has challenged the community with complex questions and identity problems. To a largely extent, distances of the young from religion and thus social solidarity cohesion are greatly enlarged. This has resulted in the young generation getting distant from the authentic norms. The values and customs have become a blind imitation of modern phenomena, submission to external influences and temptations. This includes, adopting strange behaviors to the community and in the absence of a communal dialect with the religious people, parents or qualified leadership and without guidance and educated choice. This causes the transition from traditional society to modern society to become more complicated. When the distribution of the population by age group and statistical data in Israel is examined on a regular basis each year. It is found that the vast majority of the monotheists "Druze" population is aged 30 and under (CBS 106/2017). Those aged 70 and over, have become a marginal minority in numbers and influence the social processes. The middle generation at the ages of 31-69 years is the parents' generation, whose status as educating figures and designers is significantly damaged. From all of the above, it can be concluded that the immediate and religious spiritual sources may be strong enough, but they do not approach all the individuals living in the monotheist "Druze" society. In the absence of access to sources and in the absence of deliberate and directing spiritual leadership, a situation arises in which there are many external influences. This sometimes it is not even understood how or why they were adopted. The result on the collective level is that the monotheists "Druze" do not know where to go. From the religious aspect, the woman is supposed to receive full protection, understanding, blessing and respect. However, the son and the husband because of distance from legitimate sources and religious laws often undermined this status (Za'eb from Dana,

1998: 121). From now on, it seems that more necessary than ever it is necessary to combine the monotheists "Druze" clergymen and scientists, with a concentrated effort to build integrated institutions that will bring together the segments of the "Druze" community to some uniformity. The role of these integrated institutions is to establish an intelligent discussion of the beliefs, principles and religion and adaptation to the modern age. In addition, this includes discussions regarding adults, youth and to working in the community according to an integrative built-in program. Moreover, directing the path of the monotheists "Druze" community to the design of its solidarity and communal coherence. Also, increasing awareness of the religious nature of the community and highlighting the foundations of ethnic identity that characterize the broadest common denominator of the monotheists "Druze".

## References

- Brain, R. *Friends and Lovers*. New York,(1976).
- Firro, K. *A History of the Druze*. E. J. Brill, Leiden, (1992).
- Helms, J. *Black and White racial identity: Theory, research and practice*. Westport, Connecticut: Greenwood Press, (1990).
- Ladislav, H. *Kinship, Honor and Solidarity: Marriage in the Middle East*. Tiptree Essex, Anchor Press, U.K.p.1, (1989).
- Layish, A. *Marriage, Divorce and Succession in the Druze Family*, Netherlands: F.J. Brill, Leiden,(1982).
- Osterreich, H. *Geographical Mobility and Kinship: A Canadian Example*. In :R. Paddington (ed.), *Kinship and Geographical Mobility*, E.L. Brill, Leiden, (1965): 131-144.
- Abu A'zz A-Din Najla. *A-druze fi a-Tarikh (The Druze in History)*, Lebanon, Beirut: Dar Ielmalayin press, Ala'lam (1990).
- Abu Torabi, G. Man Hom *Almowahdoon A-Druze (Who Are The monotheists Druze)*, Syria, Damascus: A'laa A-din Press,(2003).
- Alhalabi, A'bbas. *(Almowahdoon A-Druze: T'akafa, Tarikh wa Resalh. (The monotheists Druze:Culture, History & Message)* Lebanon Beirut:Dar Anhar Press, (2008).
- Hasin, K. Taef A-Druze *Tarekhaha wa A'kaedaha .(Druze Community : History & Faith )* Egypt: Dar Al Ma'aref press, (1968).
- Noihed', N. *Nesaa min Baladi (Women from my Country)*, Lebanon, Beirut: Dar Alhadatha press, (2000).
- Taki A-Din, H. Adil . *Almrah fi Mogtama' Almowhadin A-Druze bin Alams walyom , ( The Woman in the society of The Monotheists Druze between past & present)* Lebanon, Beirut: Dar AlHikma press, (2007).
- Talea', A. *The Reincarnation*, Lebanon: ma'rad' A-shof press, (2001).
- Zher A-Din, S. *Tarikh AlMoslmin Almowahdin A-Druze, (History of The Monotheists Muslims- The Druze)*, almarkiz Ala'rbi Lilabhath, Beirut, Lebanon, (1994).
- Central Bureau of Statistics Israeli . [www.cbs.il](http://www.cbs.il) .106 , April 25 (2017).
- Falah', S. *The Druze in Middle East*. Jerusalem: Security Ministry, Keter press, (2000).
- Granot, T. (1985). *The Loss, its effects & the confrontation with it*. Tel- Aviv: The Defense, 1985. of Ministry
- Halaby, Ramzi. *Economic Leadership & Enterprisers in Israeli Druze Community*. Israel: Asia press, (2009).
- Hassan, Y. *Changes in Druze Settlements as a Result of their Integration in the Israeli Security System*, Haifa University: master research, (1992).
- Ma'di, K. *The Druze Woman*. P. 110.Ed. Dana, N. The Druze, Rmat Gan: Bar-Ilan university, (1998).
- Sa'eb, A'. *The Necessity to Change The Current Status of the Druze Woman*. Dana, N. Ed. The Druze. Rmat Gan: Bar-Ilan university, (1998).
- Saleh, Shakib, *History of Druze*, Bar Elan University, Jerusalem: Dapi Noi press, (1989).
- Sofer, A. *The Druze in Israel- Geographic aspects*. Ed. Dana, N. The Druze, Rmat Gan: Bar- Ilan university, graft press. P.188- 192, (1998).

## Digital game – game or danger?

Mhana Khatib\*

West Timisoara University

---

### Abstract

Due to the centrality of digital games in the leisure culture of children and teenagers, it is especially important to understand the impact of violent digital games on this age group. A large part of the digital games, including multiplayer games that have become part of almost all types of users in recent years, include a main component of violence. This paper purpose is to examine the risks and dangers to children and teenagers from modern computer games. The complexity of the issue of risk perception in modern society and aggression are concepts that have been researched in the past. However, there are few researches of the changes in these perceptions due to the technological development of the internet, computer games, and the increasing use of it at home, especially by teenagers. It is very important to understand how children and adolescents perceive the dangers of computer games, how this affects their socialization process, since many theories dealing with health risk behaviors claim that the risk perceptions are a main and important component in shaping risk behaviors.

*Keywords:* Risk; Internet; Digital games; Compulsiveness; Aggression, Cyberbullying.

---

### 1. Introduction

Digital games are an integral part of the daily routine of children and teenagers. More than 95% of them spend a large part of their free time to it (Greenberg, Sherry, Lachlan, Lucas & Holmstrom 2010). Since many of the games contain blatant elements of violence, by the last few years there is an argument regarding the influence these games have on violent aspects of the personalities and behavior of the players. Due to the centrality of digital games in the leisure culture of children and teenagers, it is especially important to understand the impact of violent digital games on this age group. A large part of the digital games, including multiplayer games that have become part of almost all types of users in recent years, include a main component of violence.

Most teenagers in modern western societies use the internet and computer games in various places (home, school, friends) and on various devices (computer, tablet, cell phone). According to a survey performed in the United States in 2010, 84% of ages 8-18 have access to the internet from their homes, an increase of about 14% of the estimated home-based approach five years earlier, and it was also found that young people spend about two and a half hours a day using computers (Rideout et al., 2010). In Europe, 60% of ages 9-16 use the internet almost every day, for an hour and a half on average, and the average age of joining is 9 years old (Livingstone et al., 2011). In Israel, 86% of ages 12-18 use the internet every day (Dror & Saar, 2012).

### 2. Risk behaviours on the Internet

The involvement of adolescents in dangerous behaviors is considered a natural and normal developmental phenomenon. According to the article of Greene et al (Greene, Krcmar, Walters, Rubin & Hale, 2000), there are two ways to look at this phenomenon: the first, as a normal developmental stage in which adolescents seek the appropriate behavior, and the second, as a negative by-product of cognitive development, i.e. egocentrism. According to the

---

\* Corresponding author. Tel.:972528703828  
E-mail address: mhana\_ch73@walla.co.il.

normal / adaptive approach, involvement in risk behaviors is associated with a poor assessment of the risk in a given situation resulting from lack of maturity or lack of experience. According to the egocentricism approach, which characterizes adolescence so much, there are situations in which adolescents find it difficult to recognize the need for judgment since they are overwhelmed by feelings of lack of vulnerability and uniqueness. One of the arenas where the adolescent's misjudgement may lead them to behave dangerously is the internet environment. For example, their flawed consideration may cause them to reveal sensitive information about themselves, to bully others or to make contact with strangers. The unique characteristics of the internet - anonymity, asynchrony, lack of social clues, wide distribution, the distance created by the network, which reduces inhibitions and emotions of empathy, ease of operation and use, availability, absence of time and space limitations, infringement of home privacy and lack of supervision and control mechanisms (Valkenburg & Peter, 2011), all these may contribute to an increase in risk behaviors on the internet, to the expansion of the circle of children and adolescents participating in them, and to the exacerbation of behavioral outcomes. . Anonymity can stimulate impulsive behavior that can lead to the removal of inhibitions, aggressiveness, sending abusive messages, harassment and cyber bullying towards members of the peer group (Valkenburg & Peter, 2011). The asynchrony of online communication enables users to read, think, and change the messages they write before they are sent (Walther, 2007). This feature of communication technology can be used improperly by formulating messages so carefully that they become particularly painful to the recipient (Valkenburg & Peter, 2011). The high availability of the internet allows young people to communicate easily with others with malicious intentions and become a target for online sexual solicitation.

Valcke, Wever, and Van Keer & Schellens (2011) proposed a synopsis of the internet dangers to adolescents according to which the internet dangers are divided into three domains: content hazards, communication hazards, and commercial hazards. Content hazards refer to children's exposure to potentially harmful content (pornography, violence, racism, false information). Commercial hazards refer to the involvement of children in consumer activity, sometimes unconsciously, through games that include hidden offers for the sale of "brand communities" products aimed to young people in the internet and advertising of food and drink products.

### **3. Digital games**

A digital game is an interactive program for one or more players, meant to provide entertainment at the least, and quite possibly more. An adaptation of 'traditional' game systems, with rules, player representation, and environment managed through electronic means. There are some definitions for it:

- Any game played using electronic device, either online or stand-alone.
- The result of the interaction of the player with an electronic system or computer is to be displayed via a display or similar display system.
- Is an interactive program enabling one or multiple players to engage with the content primarily for entertainment purposes.
- Popular form of entertainment and media use, which also offer possibilities for learning. Digital games are designed for play with e.g. a computer, videogame console, mobile device or interactive televisio.
- An electronic game in which players control images on a television or computer screen.
- Any game that is controlled by and displayed on an electronic device or computer.
- A computer game is a software program in which one or more players make decisions by controlling game objects and resources, in the pursuit of its goal.
- A set of challenging and/or novel experiences, scenarios, or decisions, structured by rules and/or goals, and mediated by a digital electronic device.
- A game whose system is (partly or wholly) implemented in a digital device such as a game console, a personal computer, a smart-phone or tablet.
- An electronic creation, recreation, or adaptation of a game; a type of play activity where the participants agree upon a set of rules that they follow and is decided by luck, skill, or strength.
- Digital games are play in single or multi-player games over the internet.

Violent contents have become common in digital games and the popularity of violent digital games increases when it contains many violent effects. Digital games can be played in a competitive or collaborative manner. In a competitive game strategy, players try to keep others from winning or getting a game resource. In contrast, in a cooperative game strategy, players help each other achieve a common goal, and the success of one player is the success of all. The influence game strategy on current player aggression after the game, findings show (Schmierbach, 2010) low level of aggression among players who have cooperated with others against the computer as a rival (cooperative mode) compared to those who played alone against the computer as a rival (solomode) and those who played alone against a



human rival (competitive mode), suggesting the possibility of reducing the level of aggression by adopting a cooperative strategy during a violent digital game

As for the effect of interaction between basic aggression and game strategy (competitive / cooperative), among low aggressors, the current level of aggression remains unchanged before and after the game, both cooperative and competitive, while among those with high level of aggression there was a decrease in the level of aggression in a cooperative violent game, compared to an increase in non-violent competitive game (Dubi, 2012)

Compulsive use of the internet is the pattern of internet use in general or in specific applications that cause disturbances in person's life, but does not imply illness or addictive behavior (Morahan-Martin, 2008). Examples of the characteristics of compulsive use of the internet are use which harms sleep, relationships with significant people, proper functioning in work or learning, and unceasing thinking about the next opportunity to connect to the network (Young, 1998).

Unlike compulsiveness of using digital applications that have an off-line version, like gambling, compulsiveness the using games is unique to the digital medium (Charlton & Danforth, 2007).

#### **4. Aggression of players in violent digital games**

The research literature relates to aggression of two different types: aggression baseline that is the trait of participants, while current aggression is violent behavior of the participant in a given moment. Aggression baseline is a multi-dimensional trait that includes four factors (Buss & Perry, 1992): physical aggressiveness, verbal aggression, anger and hostility.

Concerning the consequences of violent games on aggressive behavior outside the game, in the study of digital games, different theoretical approaches with contradictory predictions can be found (Bösche, 2009). General Aggression Model (GAM) (Anderson & Bushman, 2002) claims that exposure to violence in a digital media will necessarily lead to increase of the current level of aggression. According to the model, consumption of violent digital games increases violent behavior outside the game and reduces empathy, both in the short and long term (Anderson & Dill, 2000). Players who persist in violent games are characterized by high basic aggression (Bartholow, Bushman, & Sestir, 2006) and more forgiving attitudes towards violent behavior (Weber, Ritterfeld, & Mathiak, 2006) compared to non-persistent players.

Other researchers point also the positive side of violent digital games (Bösche, 2010). Some claim that violence in a digital game allows catharsis to release aggression harmlessly in the game environment and thus reduce violent behavior outside the game (Ferguson et al., 2010).

##### *Cyber Bullying*

Cyberbullying is defined as "behavior carried out through electronic or digital media by individuals or groups that repeatedly transmit hostile or aggressive messages with the intent to cause harm or inconvenience to others" (Tokunaga, 2010, p.278) it can be done in various ways, including sending an offensive text or images, prevention or exclusion from activities, threats, use of derogatory names and insults (Jovonen & Gross, 2008), and more. It is customary to divide the children involved in cyberbullying into three groups - network victims, cyberbullies, and witnesses (Treblus et al, 2011). There is a growing number of researches that speak of another group - victims / cyberbullies that grows rapidly. Moshna et al. (2012) report that 26% of the participants in the research belonged to the group of victims / cyberbullies. Li (2007) claims that the chance of being a victim of cyberbullying on one hand and cyberbully on the other is big and stems from belonging to an active social group whose members tend to harass each other in the group. This implies that cyberbullying behavior becomes part of the accepted behavior in the peer group.

The literature shows correlation between traditional bullying and cyberbullying, i.e. bullies in physical life tend to be cyberbullies, victims in physical life are also tend to suffer of cyberbullying (Talmud, 2013). Yabarra et al. (2007) performed a research among 10-15-year-old who reported that 36% of children experienced traditional bullying and cyberbullying, 13% of them of the same attacker. Another research found that 54% of the students were victims of traditional bullying, and a quarter of them were also harassed via the internet (Li, 2007). These findings indicate a continuum between bullying behavior in the real world and in the virtual world. The internet has become an additional arena of activity, but due to its unique characteristics (anonymity, distance that reduces inhibitions and empathy, independence of time and space, ease operation and widespread distribution), the number of participants - both attackers and witnesses - has increased since the digital environment allows children who have refrained from traditional bullying to engage in cyberbullying (Tokunaga, 2010).

Digital space allows attackers to more easily evade the consequences of their actions because children and adolescents avoid involving adults in their experiences for a variety of reasons. Adults are perceived as strangers in virtual culture and therefore the children fear that they will not understand them. The children also believe that bullying cannot be proven or that the attacker cannot be found, or they fear that adults, in order to protect them, will deny them access to the network and this is perceived by them as punishment (Mishna et al., 2012). Therefore, action to reduce the phenomenon should be carried out in the educational preventative level, which requires an understanding of the risk factors of cyberbullying.

## **5. Cases that took place in Israel during 2015-2017**

1. Two teenagers from Jerusalem area got out to have fun, drank some alcohol, and on their way home bumped into a homeless man who slept on the bench in a public park. They asked a cigarette from the homeless, he didn't have any, so the teenagers decided to beat him with a tree plank they found in the park. They attacked the homeless man who is about 60 years old, seriously hurt him and left in the part till he died. The two teenagers were arrested later and claimed that from their point of view it was a game. The homeless man cursed them and they thought that, like in the computer games, they can hit him and "nothing will happen". The closer examination revealed that the two of them really liked violent computer games, and their behavior in front of the helpless person was a replication of their games' behavior. They did not pay attention to the fact the man was bleeding and needed medical help.

2. A boy 15 years old from one of the north villages decided to revenge on other pupil from the same class who did not help him on exam. He wrote a post telling the other boy loves "caressing". The excellent pupil got disturbed and bothered by other pupils from the class, who laughed at him and humiliated him. From the moment the post was published, he started deteriorating in his school achievements and sometimes preferred not to go to school at all. The parents were informed by the school authorities, the boy was treated by psychologist, changed the school and never got back to it.

3. A 15-years old girl who dated a guy who was 17 years old was taken picture when making sex, without her knowledge. The guy blackmailed her and threatened to publish the movie. The parents and authorities did not know anything about it till the girl decided to commit a suicide. She was rescued and then the story became known. A police investigation found the guy. He didn't feel any regrets. In his vision, there are lots of similar movies made all the time, so nothing wrong can be found in his actions. His lawyer argued that his client is innocent since he learnt from the internet- a place open to everybody.

## **6. The research method**

In my research I used various tools. After an exploratory research, I performed a semi-structured interview. The interviewee was asked to tell about his experience of participating violent digital games and the personal process he goes in these games. A semi-structured interview is a phenomenological interview aimed at obtaining a detailed image of the person's world perception and belief in the examined subject (Fontana & Frey, 1994). The advantage of this interview is in its flexible and dynamic structure that enables freedom and dialogue between the interviewer and the interviewee (Bogdan & Taylor, 1984). The questions related to the following subjects: sense of belonging to the game group, the number of friends in the game context and the nature of the relationship with them, the compulsiveness of using the game (according to Young's criteria, 1996), and the expression of aggression in the game if exist. The goal of the interview was to ensure dealing with the subject and all its aspects, however, this flexible structure enabled freedom and dialogue between the interviewee and the interviewer when the interviewee was able to "speak out", to describe his personal experience as a player, lead the interview and raise points significant to him within the subject.

## **7. Research hypotheses**

In this research, the author examined the research hypotheses that the interaction effect between the social (cooperative / competitive) context of the game and the basic level of aggression (low / high) of the participant on the sense of belonging to the game community, the number of members in the social network, and the level of compulsiveness of using the game will be found. Participants with high level of basic aggression will be more affected from violent competitive games than people with low baseline aggression.

The interaction effect between the basic level of the participant's aggression (high / low) and the type of game (interpersonal / group) on the sense of belonging to the game community, the number of members in the social network, and the level of compulsiveness of using the game will be found. Participants with high level of basic aggression will be more affected from violent multiplayer games than people with low baseline aggression.

## 8. The research findings

The findings of the qualitative research indicated that compulsiveness of using the game mainly depends on the player's personal factors rather than on the game design. Comparing the criteria of the questionnaire of compulsive use of internet (Young, 1996) with the interviewees' claims, shows there is a great similarity between the two cases in the symptoms of compulsive use of the game, as anticipation of the next login, discomfort when login is not possible, harming social connections or symptoms of compulsive use of games according to family members' report. Some of the interviewees showed the understand that this was compulsive behavior and tried to reduce the impact of the game on interpersonal interaction outside the network, while others preferred to associate the compulsive symptoms of other players. However, most of the interviewees described a similar process they have experienced when they started to play, they spent a lot of time playing, felt a difficulty in disconnecting from the game, and described situations in which the game took control of their lives. But as liabilities increased, their ability to regulate the time spent in the game improved. The game is a kind of substitute for interesting engagement and the escape to the game environment is growing and tends to be less controlled as the player has no other interesting alternative for leisure.

The findings showed that the compulsiveness of the participants is not a dichotomous but spreads on a scale in which on one end there are the players that explicitly referred the shift to limited use in violent game as a legitimate way to release pressure in the harmless game environment, while at the other end are players who describe their compulsive behavior and totally ignoring the negative consequences these games have on daily life.

## Summary and conclusion

Therefore, it can be concluded that the collective - group game has an advantage over the competitive - interpersonal game in terms of increasing the sense of belonging to the game community. It is therefore possible to recommend players with a low level of aggression who cannot sense a strong sense of belonging to the game group in competitive strategy and in interpersonal games to play group games in a cooperative strategy so they could feel more belonging to the game group and to win more friends. In addition, the findings show that there is no fear that low-aggressive individuals will become compulsive players. On the other hand, players with high baseline aggressiveness should avoid or limit the use of violent digital games that may lead to compulsive use, although this can sometimes increase the circle of their friends, even if it is collective games or group games.

As for the implications of violent digital games on the behavior of the players in the game environment, we have seen that these games enable the release of negative emotions in the game environment according to the catharsis theory that claim that alleged violence in a digital game enables violence release in the game environment and thus reduces violent behavior outside it (Ferguson et al., 2010). According to the quantitative and the qualitative analysis it seems that the player's character has a decisive influence on the negative projection of violent digital games - players with a predisposition to aggression will play the game more obsessively than less aggressive players, mostly regardless to the type and strategy of the game.

Comparing the criteria of the questionnaire of compulsive use of internet (Young, 1996) with the interviewees' claims, shows there is a great similarity between the two cases in the symptoms of compulsive use of the game, especially according to a new meta-analysis, the level of compulsive use of internet in the Middle East is the highest in the world, when Israel is one of the four Middle Eastern countries that entered the analysis (Cheng & Li, 2014).

## References

- Anderson, C. A., Bushman, B. J., *Human aggression. Annual review of psychology*, 53(1), pp 27-51, (2002).
- Bartholow, B.D., Bushman, B.J. and Sestir, M.A. *Chronic violent video game exposure and desensitization to violence: Behavioral and event-related brain potential data. Journal of Experimental Social Psychology*, 42, pp 532 539,(2006).
- Bösche, W. *Violent content enhances video game performance. Journal of Media psychology: Theories, Methods, and Applications*, 21(4), pp 145, (2009).
- Burton K.A., Florell D.and Wygant D.B. *The role of peer attachment and normative beliefs about aggression on traditional bullying and cyberbullying. Psychology in the Schools*, 50(2), pp 103-114, (2013).
- Chapin J.. *Adolescents and Cyber Bullying: The Precaution Adoption Process Model. Education and Information Technologies*, 1-10, (2014).

- Charlton, J. P. and Danforth, D. W. *Distinguishing addiction and high engagement in the context of online game playing*. Computers in Human Behavior, 23, pp 1531-1548.( 2007).
- Dubi, T. and Eden, S. *The impact of violent digital games and strategies play on the level of aggression in children*. In: Eshet-Elkhalai Y., Kaspi, A., Eden, S., Geri, N., Yair, Y. and Kalman Y. (editors), *The Seventh Conference of Chais Research and Innovation in Technology: Learning in the Technological Era*, Ra'anana: The Open University, pp. 70-79, (2010).
- Greene K., Krcmar M., Walters L.H., Rubin D.L., Hale L. *Targeting adolescent risk- taking behaviors: the contributions of egocentrism and sensation seeking*. Journal of adolescence. 23, pp 439-46, (2000).
- Greenberg, B. S., Sherry J., Lachlan, K., Lucas, K. and Holmstrom, A. *Orientations to video games among gender and age groups*. Simulation Gaming, 41(2), pp 238-259, (2010).
- Juvonen J., Gross E.F. *Extending the school grounds? Bullying experiences in cyberspace*. Journal of School Health Association, 78 (9), pp 496-505, (2008).
- Livingstone S., Haddon L., G rzig A., Ólafsson K.. *Risk and Safety on the Internet*. LSE London School of Economics and Political Science, (2011).
- Tokunaga R.S. *Following you home from school: A critical review and synthesis of research on cyberbullying victimization*. Computers in human behavior 26, pp 277-287, (2010).
- Trebelus T., Heiman T., Olenick-Shemesh D. *Internet violence versus face-to-face violence among youth*. Chais Conference on Learning Technologies Research, conference book. (2011).
- Valcke M., De Wever B., Van Keer H., Schellens T. *Long-term study of safe internet use of young children*. Computers & Education 57, pp 1292-1305, (2011).
- Valkenburg P.M., Peter J. *Online communication among adolescents: An integrated model of its attraction, opportunities and risks*. Journal of Adolescent Health, 48, 121-127, (2011).
- Walther J.B. *Theories of Computer Mediated Communication and Interpersonal Relations*. In Interpersonal Communication, edt. Knapp M.L., Daly J.A. SAGE Publications, (2011).
- Weber, R., Ritterfeld, U., & Mathiak, K. *Does playing violent video games induce aggression? Empirical evidence of a functional magnetic resonance imaging study*. Media Psychology, 8, pp 39-60, (2006).
- Young, K. S. *Internet addiction: The emergence of a new clinical disorder*. CyberPsychology & Behavior, 1, pp 237-244, (1998).

## Change management process and its characteristics in schools

Sarsour Raed<sup>a</sup> \*, Sarsour Alaa<sup>a</sup>

<sup>a</sup> West Timisoara University- Romania

---

### Abstract

Teachers know education does not stand still, and welcome thoughtful and coherent change that is in the best interests of students. Change will inevitably impact on teachers because the learning conditions of students are also the working conditions of teachers.

Educational institutions have more and more power to decide both on financial and operational matters. Who exercises this power in reality is therefore not insignificant. The opinions of leaders and principals are reflected in the decisions being made – some more than others. New opportunities have also brought about more and more responsibility for the effects of decisions and the relative weight assigned to different functions.

One of the most obvious changes currently occurring is the change in the relative global population distribution between countries. In the recent decades, developing countries became a larger proportion of world population, increasing from 68% in 1950 to 82% in 2010, while population of the developed countries has declined from 32% of total world population in 1950 to 18% in 2010. China and India continue to be the largest countries, followed by the US as a distant third. However, population growth throughout the world is slowing. Population growth among developed countries has been slowing since the 1950s, and is now at 0.3% annual growth. Population growth among the less developed countries excluding the least developed has also been slowing, since 1960, and is now at 1.3% annual growth. Population growth among the least developed countries has slowed relatively little, and is the highest at 2.7% annual growth.

With the global world changes, also the schools change, which makes it inevitable to change schools' management. School management has become an increasingly important factor in the education policy debate. As resources become scarcer while demands are growing, issues relating to management, leadership and principalship emerge in a new light. At the same time, the extensive nature of management becomes more prominent. School management is not only about administrative management but also about pedagogical and knowledge based leadership. Leadership and leaders still play a crucial role in terms of school development as well

The research was conducted in Arab-speaking schools in Israel. 200 head teachers participated and gave their opinion about the need and the possibilities of management change in school. The most of them are ready for changes and also claim the community is also ready. However, there are lots of administrative and organizational obstacles on the way of a true change. The field study came to the following conclusions and recommendations: There should be a policy in the Education Ministry that encourages the implementation of a new management in schools; Individual differences among school needs should be taken into considerations; The teacher should diversify from the methods of explaining the subject using the technology; Enough time should be given to head teachers to use management in education; The school administration should encourage teachers to use computers, telegrams and all means in education.

**Key words:** Change; Management; Process; Education; Teachers; Schools.

---

### 1. Introduction

One of the most obvious changes currently occurring is the change in the relative global population distribution between countries. In the recent decades, developing countries became a larger proportion of world population, increasing from 68% in 1950 to 82% in 2010, while population of the developed countries has declined from 32% of total world population in 1950 to 18% in 2010. China and India continue to be the largest countries, followed by the US as a distant third. However, population growth throughout the world is slowing. Population growth among developed countries has been slowing since the 1950s, and is now at 0.3% annual growth. Population growth among the less developed countries excluding the least developed has also been slowing, since 1960, and is now at 1.3% annual

---

\* Sarsour Raed. Tel.: +972507535212;  
E-mail address: raedsarsour10@gmail.com

growth. Population growth among the least developed countries has slowed relatively little, and is the highest at 2.7% annual growth (Bjørnholt, 2014).

With the global world changes, also the schools change, which makes it inevitable to change schools' management. School management has become an increasingly important factor in the education policy debate. As resources become scarcer while demands are growing, issues relating to management, leadership and principalship emerge in a new light. At the same time, the extensive nature of management becomes more prominent. School management is not only about administrative management but also about pedagogical and knowledge based leadership. Leadership and leaders still play a crucial role in terms of school development as well (Boikhutso, 2013).

Many researches study mainly concentrates on the last two decades, years of 1990–2010, changes that have influenced school management have definitely been made earlier. Changes in different decades can be viewed as forming a chain of changes, which has resulted in current school management. Based on doctoral research examining principals' operating environments, work, role and identity development over the last ten years, the chain of changes seems to have culminated during the last two decades (Burnes, 2004).

The operating environments and duties of principals of the 1980's and the 2000's are significantly different from each other (Risku et.al., 2014). It can also be presumed that the chain of changes will continue and become even more intense. Based on these assumptions, many researcher looks for improving the enthusiastic characteristics of change management process in schools.

## **2. Discussion of the need for change in school management**

This study presents some basics regarding change management and it does so from several perspectives, including those of change management as:

- (1) the task of managing change,
- (2) an area of professional practice,
- (3) a body of knowledge and
- (4) a control mechanism.

It also examines change management as a matter of problem finding and problem solving and it reviews some basic change management strategies and required skills.

Change management is one of the biggest tasks in which a business may be involved. It is a deliberate approach in the bringing major changes for meeting people's expectations to move the business forward smoothly (Cameron and Green, 2004, p. 65).

When the need for change arises, organizations and businesses have no option, but to respond— or else they will lose their competitiveness in the market. Burnes (2004): states that change management can support a range of change projects, including the implementation of a new process, new systems, updated structures, or technology – in the establishment of a new working culture or set of values in any particular area. Changes in society are changes in education, and changes in education change the place that the educational institutions have in the country, and that inevitably leads to changes in running and managing with the educational institutions. Changes in order to increase the quality of management towards improving the quality of educational services to the demands of the modern times. Only a modern management is appropriate to modern times. The director, as a lead character in the implementation of management in schools, has the responsibility of coping with the needs of modern times, setting goals and scoring in a high level, because living means solving problems, and growing means greater ability to solve bigger problems (Burnes, 2004).

## **3. Resistance to change**

Often, there is unwillingness to change, both from the employers and management and the employees' side.

A long established assumption in the literature on organizational change is that resistance constitutes a problem. For example, in Coch and French's (1948) seminal study in a US pyjama sewing factory, employees reacted to being moved to different jobs by quitting, being absent, restricting output and showing hostility towards management.

It was concluded that this behaviour constituted resistance to the change and, accordingly, the study was designed explicitly to examine why people resisted change so strongly and what could be done to overcome such resistance.

This problematizing of resistance was then taken up by Lawrence (1954: 49), who argued that employee resistance to change was one of "the most baffling and recalcitrant of the problems which business executives face." Other studies followed, which also focused on overcoming resistance (e.g., Zander, 1950), especially in the Organization Development (OD) approach to change (Cummings & Worley, 1997).

Even processual and political approaches (Maurer, 1996), which criticized OD for failing to capture the "messiness" of change, explicitly acknowledged the strong possibility of resistance and treated it as something that needed to be overcome – an assumption which continues to be popular today.

Not surprisingly, studies went on to investigate the causes of, and solutions to, resistance. Causes were typically conceptualized in terms of shortcomings in an individual's attitudes, emotions and/or behaviors (Piderit, 2000).

For example, parochial self-interest led employees to resist because they focused on "their own best interests and not on those of the total organization" (Kotter & Schlesinger, 1979: 107).

Change is a firmly established priority for organizations. The 1980s and 1990s saw organizations experiment with TQM, customer service initiatives, reengineering, right-sizing, downsizing, culture change, and countless other managerial fads and fashions (Reichers, Wanous & Austin, 1997).

More recently, global environmental, technological and financial shocks have forced organizations to adapt and transform their activities (Bennebroek Gravenhorst & In't Veld, 2004; Bercovitz & Feldman, 2008). To realize such changes, it is commonly held that successful change requires the cooperation of employees, since any resistance on their part can hamper the change initiative (Piderit, 2000).

#### 4. Experimental study in Israel

The sample of the study included 200 male and female head teachers who teach at school of Israel in 2018. The researcher selected them randomly from Arab- speaking schools. 55% of the sample were males, the rest- females, most with BA academic degree. Questionnaire for collecting information about "change in management" was developed based on previous studies dealing with the same subject. Surprisingly enough, most of the respondents (about 81%) agree there is a need for change in managing an Arab school in Israel. Most of them (60%) agree that head teachers are ready to accept changes and implement them in classes. Change management is a positive phenomenon in Arab schools- this is the opinion of most of the respondents (88%). However, less of them are enthusiastic about the school system ability to make changes- due to organizational, administrative reasons, but not social ones. No significant differences were found between males and females in their attitudes towards changes, neither were differences in answers of respondents with different education levels.

#### 5. Conclusions and recommendations

The world is changing rapidly, and so do the society, economics, population and education. The methods and the means of bringing up the young generation have to change, since the old ways are not working any more. Unexpectedly, most of the head teachers' in Arab-speaking school of Israel are ready for changes and understand their crucial role in the future of a teacher profession in particular and the education system in general.

The field study came to the following conclusions and recommendations:

- There should be a policy in the Education Ministry that encourages the implementation of a new management in schools.
- Individual differences among school needs should be taken into considerations
- The teacher should diversify from the methods of explaining the subject using the technology.
- Enough time should be given to head teachers to use management in education.
- The school administration should encourage teachers to use computers, telegrams and all means in education.

#### References

- Bennebroek Gravenhorst, K.M., & In't Veld, R.J. *Power and collaboration: Methodologies for working together in change*. In J.J. Boonstra (Ed.), *Dynamics of organizational change and learning*, 317-341. Chichester: Wiley (2004).
- Bercovitz, J., & Feldman, M. *Academic entrepreneurs: Organizational change at the individual level*. *Organization Science*, 19, 69-89, (2008).
- Boikhutso, M. . *Change Management: The Impact on Systems Implementation. A Business Application Solution Centre (BASC) Case Study*. University of South Africa (2013).
- Bjørnholt, M.. "Changing men, changing times; fathers and sons from an experimental gender equality study" (PDF). *The Sociological Review*. 62 (2): 295–315, (2014).
- Burnes, B. *Managing Change: A Strategic Approach to Organizational Dynamics*. Pearson Education Limited, UK, (2004).
- Cameron, E., and Green, M. *Making sense of change management* Complete guide to the models, tools & techniques of organizational change, (2004).
- Coch L. and French J. *Overcoming Resistance to Change*. *Human Relations*, 1(4), pp.512-532, (1948).
- Cummings, T.G. and Worley C.G. *Organization Development and Change*. South-Western College Pub., 609 p. (1997).
- Lawrence, P.R. *How to Deal with Resistance to Change*. *Harvard Business Review*, (May/June), pp. 49-57, (1954).
- Maurer, R. *Using resistance to build support for change*, *The Journal for Quality and Participation*, 19 (3), pp. 56-66 , (1996).

- Piderit, S. K. *Rethinking resistance and recognizing ambivalence: A multidimensional view of attitudes toward an organizational change*. Academy of Management Review, 25, 783-794, (2000).
- Reichers A.E., Wanous J.P. and Austin J.T. *Understanding and Managing Cynicism about Organizational Change*. The Academy of Management Executive (1993-2005). Vol. 11, No. 1, pp. 48-59, (1997).
- Risku, M., Pekka Kanervio P. and Björk L.G. *Finnish Superintendents: Leading in a Changing Education Policy Context*. <https://www.tandfonline.com/toc/nlps20/13/4>. Pp.383-406, (2014).
- Zander, A. *Resistance to change—its analysis and prevention*. Advanced Management Journal, 15(1), 9-11, (1950).



# Managing the implementation of Information Technology (IT) and its influence in school

Sarsour Alaa<sup>a\*</sup>, Sarsour Raed<sup>a</sup>

<sup>a</sup> West Timisoara University- Romania

---

## Abstract

In this article it was attempted to research managing the implementation of information technology in schools.

New technologies have changed teaching and learning in a number of ways from graphing calculators to online lesson plans to virtual field trips and simulated dissections, educational technologies can help students access content in new and often exciting ways. In fact, one would be hard pressed to find a single school that doesn't have access to some kind of educational technology.

To conclude, the researcher believes that information technology (IT) is a versatile and valuable tool for teaching and learning and becoming a way of life. The most important thing is that teachers need to be prepared to use these technologies effectively. Schools can use technology effectively and for the welfare of students, teachers and society, it must be done.

The sample of the study included 200 male and female technology teachers who taught at the elementary school in Israel within 2018, The researcher was selected them randomly, half were males and half females. 70% of them have a BA degree, 30%- more than BA. Questionnaire for collecting information has been developed after surveying some previous studies dealing with the same subject. The questionnaire consisting of 20 questions which are distributed into four parts (teachers, pupils, methods and surroundings).

The results demonstrate that the teachers and pupils are ready to use more actively the IT in school lessons, but the current curricula makes it difficult and does not consider individual pupils' differences.

*Key words:* Managing; Implementation; Information; Technology; Teachers; Schools.

---

## 1. Introduction

Information technology (IT) is the use of computers to store, retrieve, transmit, and manipulate data, or information, often in the context of a business or other enterprise. IT is considered to be a subset of information and communications technology (ICT). Humans have been storing, retrieving, manipulating, and communicating information since the Sumerians in Mesopotamia developed writing in about 3000 BC, (Butler, 2012), but the term information technology in its modern sense first appeared in a 1958 article published in the Harvard Business Review; authors Harold J. Leavitt and Thomas L. Whisler commented that "the new technology does not yet have a single established name. We shall call it information technology (IT)." Their definition consists of three categories: techniques for processing, the application of statistical and mathematical methods to decision-making, and the simulation of higher-order thinking through computer programs (Leavitt and Whisler, 1958).

According to surveys, as many as 95% of schools are connected to the Internet; even at the level of the individual classroom, connection is nearly as universal close to 75% of classrooms in the United States have Internet access (CEO Forum, 2000).

Despite this nearly ubiquitous access to computer technology, however, there is a significant gap between the presence of technology and its usage in the classroom. While some type of technology is present in nearly every classroom in the country, it is rarely used to its fullest potential (Royer, 2002).

---

\* Sarsour Alaa. Tel.: +972507535212;  
E-mail address: alaa.kris1@gmail.com

Some of this discrepancy is due to a lack of comfort with using technology for teaching and learning. Even teachers who are using technology and report a high degree of comfort with technology tend to use it in fairly rigid ways, such as searching for activities to use with students, communicating with other teachers, and word processing (Price, Cates & Bodzin, 2002).

And while students frequently do use computers in the classroom, use is often limited to information gathering and word processing rather than using multimedia tools or digital content to design and create products (Price et al., 2002). Often, learning with technology is teacher-centered rather than student-centered.

While many teachers still feel uncomfortable using technology in their teaching practice, it is also likely that teachers feel new technologies are unproven in the classroom (Royer, 2002). Though there has been a great deal of research on the efficacy of technology tools for teaching and learning, many of these studies may not translate well to the reality of the classroom.

## **2. The Statement of the problem**

Teaching and learning information technology (IT) is crucial for both teachers and learners. Students, teachers, schools and other stakeholders will use IT effectively as a tool for enhancing the effectiveness of learning and teaching, with a view to preparing our students for the information age, turning schools into dynamic and interactive learning institutions, and fostering collaboration among schools, parents and the community.

If schools want teachers to use technology to enhance student learning, then it is important to address these issues. Teachers are inundated with new initiatives every year; new ideas come and go and are rarely sustainable (Zorfass, 2001). To avoid "initiative fatigue," schools must focus not only on introducing new technology, but also on implementing and scaling up new technologies.

Based on these assumptions, the researcher looks for improving the enthusiastic influence of information technology (IT) in schools.

## **3. Change in Student and Teacher Roles**

When students are using technology as a tool or a support for communicating with others, they are in an active role rather than the passive role of recipient of information transmitted by a teacher, textbook, or broadcast. According to Khlooff. (2010), the student is actively making choices about how to generate, obtain, manipulate, or display information. Technology use allows many more students to be actively thinking about information, making choices, and executing skills than is typical in teacher-led lessons.

Moreover, when technology is used as a tool to support students in performing authentic tasks, the students are in the position of defining their goals, making design decisions, and evaluating their progress.

The teacher's role changes as well. The teacher is no longer the center of attention as the dispenser of information, but rather plays the role of facilitator, setting project goals and providing guidelines and resources, moving from student to student or group to group, providing suggestions and support for student activity.

Khlooff (2010) claims: as students work on their technology-supported products, the teacher rotates through the room, looking over shoulders, asking about the reasons for various design choices, and suggesting resources that might be used. (See example of teacher as coach.)

Project-based work (such as the City Building Project and the Student-Run Manufacturing Company) and cooperative learning approaches prompt this change in roles, whether technology is used or not. However, tool uses of technology are highly compatible with this new teacher role, since they stimulate so much active mental work on the part of students. Moreover, when the venue for work is technology, the teacher often finds him or herself joined by many peer coaches--students who are technology savvy and eager to share their knowledge with others.

## **4. Experimental study in Israel**

### *4.1. Study Sample*

The sample of the study included 200 male and female technology teachers who taught at the elementary school in Israel within 2018, The researcher was selected them randomly, half were males and half females. 70% of them have a BA degree, 30%- more than BA. Questionnaire for collecting information has been developed after surveying some previous studies dealing with the same subject. The questionnaire consisting of 20 questions which are distributed into four parts (teachers, pupils, methods and surroundings).

#### **4.2. Results**

Most of the respondents (70%) about agree that the teacher plays the main role through learning the students using the computer; and also that the teachers has the qualification for learning the students technology skills; about 80% agree that the teacher takes into account individual differences among students while teaching computer skills; and about 90% says that teacher uses multiple technological means in classrooms. In questions regarding the pupils: almost all the respondents agree that the student's desire for technological learning has a major role through learning process; but there are individual differences among students in learning computer skills. Most of the teachers (80%) claim that a students' awareness for the importance of computer skills plays a major role in their learning of technology. 90% say that a student who understands the importance of learning technological skills is faster than others. And to conclude, about 90% think that there is a need to conduct additional practical activities that help students master the skill of electronic devices. The school curriculum, however, is not enough suited for implementing the IT technologies in school (about half of the respondents think so), and most agree that the current curricula does not take into consideration the cognitive and emotional personal differences between the pupils. When talking about the surroundings of teaching in Israeli school, most of the teachers say that modern school uses IT greatly, but there is not enough diversity and flexibility, especially when dealing with individual differences of the pupils.

#### **5. Conclusions and recommendations**

The researcher believes that the teacher has an important and direct role in the implementation of technology through the answers to paragraphs of the questionnaire, which showed that high to very high and the teacher can encourage students to implement and use technology through classroom classes. The researcher pointed out that motivation in the student has a direct and important role in the implementation of technology at schools, in addition to the students' interaction with technology activates students in school and diversifies the methods of education. The researcher believes that there are parts in the curriculum that need some improvements: it should encourage more the use of technology, take into account many individual differences between students, be simpler to implement and use.

No differences were found between male and female subjects. The researcher attributed the absence of gender differences in the sample of the study to the fact that both male and female teachers in schools are subject to one law from the Ministry of Education and what applies to males applies to females.

##### **Recommendations**

Since the world is changing and the technologies become part of our everyday lives, there is a need to change the school curricula as well and use more technological methods of teaching.

Compared to conventional classrooms with their accent on verbal knowledge and multiple-choice test performance, technology provides a very different set of challenges and different ways in which students can demonstrate what they understand (e.g., by programming a simulation to demonstrate a concept rather than trying to explain it verbally).

A related technology effect stressed by many teachers was enhancement of student self esteem. Both the increased competence they feel after mastering technology-based tasks and their awareness of the value placed upon technology within our culture, led to increases in students' (and often teachers') sense of self worth.

Students clearly take pride in being able to use the same computer-based tools employed by professionals. As one teacher expressed it, "Students gain a sense of empowerment from learning to control the computer and to use it in ways they associate with the real world.

" Technology is valued within our culture. It is something that costs money and that bestows the power to add value. By giving students technology tools, we are implicitly giving weight to their school activities. Students are very sensitive to this message that they, and their work, are important.

- There should be a policy in the ministry that encourages the implementation of technology at schools.
- Take into consideration individual differences among students.
- Provide an environment conducive to the use of technology.
- The teacher should diversify from the methods of explaining the subject using the technology.
- Enough time for teachers to use technology in education.
- The school administration should encourage teachers to use computers, telegrams and all means in education.

## References

- Butler, J. G. *A History of Information Technology and Systems*. University of Arizona, (2012).
- CEO Forum. *The power of digital learning: Integrating digital content*. The CEO Forum school technology and readiness report, year three. Washington, DC: CEO Forum on Education and Technology, (2000).
- Khloof, E. *Reality of Implementing Electronic Management in the Secondary Government Schools in the West Bank from the Principals' Perspective*. An-Najah National University, Nablus, (2010).
- Leavitt, H. J. and Whisler, T. L. *Management in the 1980s*. Harvard Business Review, 11, (1958).
- Royer, R. *Supporting technology integration through action research*. The Clearing House, 75(5), 233-237, (2002).
- Price, B., Cates, W., & Bodzin, A. *Challenges in implementing technology-rich curricular high school biology materials: First year findings from the Exploring Life project*. Paper presented at the National Educational Computing
- Zorfass, J. *Sustaining a curriculum innovation: cases of Make It Happen!* In J. Woodward & L. Cuban (Eds.). Technology, curriculum and professional development: Adapting schools to meet the needs of students with disabilities pp. 87-114. California: Corwin Press, Inc. Conference in San Antonio, TX., June 17-19, (2001).

# The Contribution of Druze women to the development of Druze society

Faraj Faraj<sup>a</sup>

<sup>a</sup> *Sociology faculty, West Timisoara University*

---

## Abstract

A society that recognizes the value and role of a woman should nurture the woman through education in order to expand and strengthen her personality and to prepare her for public and private life (marriage, parenting and house duties). The house is the place to begin with the profound change in values that guide our lives everywhere. Thus, the woman will be able to enter the field of work to help develop the community. The role of legal Feminism is to make a change and contributes to the discrimination of women in society. The categories "women" and "men" are currently in the process of change and goes towards a justice society and creation of a new man. The honor of women is of supreme value to the Druze, who are certain that "the woman is a pearl" that must be preserved and without male preference. The status and dignity of the Druze woman has significant cultural content in maintaining the social order and the Druze identity. After the establishment of the State of Israel in 1948, changes and successes began in the manner of relations between women and men that led to a breakthrough in Druze society in Israel. The percentage of female Druze students is higher than male Druze students, a trend that over the years could lead to a change in the social structure of the Druze community. The successes were mainly in the education system and especially during the last decade. Today at the top of the pyramid in the Ministry of Education on the department of Druze sector, a Druze woman is in charge of the Druze education in Israel, a woman that was formerly to her current role a school principal and supervisor.

*Keywords:* Druze women in Israel; Druze society; development; higher education; employment.

---

## 1. Introduction

Development has become an urgent and persistent demand for all current companies. The development is extensive on significant topics such as: social, economic, political and important cultural issues. This also effect current and future societies. Today, the main goal of development is to answer the needs and happiness of humans. In order to develop a proper and successful society, the society must pay attention and focus on all human energies without discrimination between women and men (Yoram Harpaz, April 2008).

Women constitute half of human society and half of its outputs forces, so any society that would like to reach the benefits of women involvement by participation of women in social and economic development should eliminate all forms of discrimination. (Jones Johnson Lewis, 2017). A society that recognizes women's value and there significant role must invest in education in order to expand women's abilities and strengthen personality characteristics in order to enable women to fulfill adequate role in the family and be able to enter workforce that will assist in production and community development (Abbas, 2010). Training women properly gives them the ability to live comfortably and reliably and have the ability to innovate and create. The more Druze women receive a greater share of education, the more they are able to understand and influence negative influences and to resist them (Wiener-Levi, 2004).

The Druze society in Israel was designed for many years by religion, when the social-traditional framework and the living conditions determined the individual's connection to his community (Yitzhak, 1998). The Druze religion calls for equality according to the laws of legitimacy written by the Druze prince Al- mir al-Assayid from Lebanon, who gave an integrated picture of the role and status of women in society. He compared men and women with religious duties, responsibility, reward and punishment. Among other things, he arranged all personal status issues and anchored them in laws that serve as the basis for Druze personal law (Fuad Abu Zaki, April 1997). The Druze religion gave Druze women the freedom to choose and decide, and the right to choose who to marry. It also gave women the right to divorce their husbands, and gave them a strong status for dignity and equality between men and their right to participate actively in life. In other words, the Druze religion espouses equality between men and women, and the woman can serve as spiritual leader of the Druze community, and moreover, equality in inheritance (Marcel Nasser, 1997). Therefore, the

\* Corresponding author. Tel.: +972-4-8395412; fax:+972-4-8396383.  
E-mail address: faraj667@gmail.com

status of Druze women in society and in law provides a solution to basic human rights, rights of life, equality, dignity, liberty, family and personal security. This approach places the issues of the "status of women" as issue of "human rights." (Orit Kamir, 2000). In author's opinion, if the members of the community implement the Druze religious laws, the Druze society will be the most advanced society in the world. And today the world is developing an interest in feminism, and feminism is a set of beliefs and ideas belonging to a social and political movement whose goal is to achieve greater equality and freedom for women (Bell Hawkes, 2002). The role of the legal feminism as embrace change function, is itself part of the mechanism that contributes to the discrimination of women in society (Noya Rimalt, 2010).

The categories "women" and "men" are subject that can be change and are currently in process of changing. The distinction between them is becoming increasingly blurred, not least because of feminism (Yoram Harpaz, echo of education, April 2008). Today we see difficulties in dealing with the gaps between the old and the new, and emphasize the conflict between the preservation of culture and the unique identity and the environmental pressure that emerges from modern culture (Saleh, 1999). The author supports the women's struggle for liberation and the establishment of a right society, and observe that change that defined as "a new man". As a Druze person, the author believes that if we implement the basics of the religious laws and values that we espouse in our society, we will succeed in educating our children and achieve gender equality.

The roots of Druze education, both religious and non-religious, are characterized as:

- Prohibition of drinking alcohol, gambling and smoking.
- Protect women honour.
- Ignore and throw away superstitions and not to believe in them, and to rely on reason and common sense (Fuad al-Attrash, 2003).

On the other hand, the foundations of Druze social education are emphasized and recommended to stay away from ostentatiousness and pornography. The Druze man must preserve the honour of the woman as he keeps his own life, in order to achieve sobriety and serenity. The Druze raised the issue of protecting women's honor as a supreme value according to the Druze religion. And anyone who does not respect the honor of woman (mother, sister, aunt, or any Druze girl...) finds himself in distances from religion and society. Preserving the honor of women is a supreme value among the Druze because women are pearls that must be preserved without male preference (Abbas, 2010). It is necessary to invest in the education of Druze woman, raise her awareness and give her full rights. And finally to have part of fathers' inheritance in order to preserve its existence and dignity (Marcel Nasser, 1997). This "pearl", meaning a Druze woman, consider as the best women in the world, and the most respected ones. On the same time, regarding the Druze society, the man must preserve his dignity and respect for the woman. Thus it is possible to build a healthy and correct society with a proper social order. The good manners among the Druze are part of the religion, and the Druze characterized by high morality, integrity and people of grace (Dana, 1974). Today, the big challenge we face beside all the nations of the world, after the imposition of the almost universal spiritual and ideological approaches, both economic and politics, has become programmed. Yes, here is the main challenge: Will the Druze maintain its values and principles? Will he preserve his identity as a bridge between the social connection and the personality of the individual, his personal values framework and the living conditions determined the individual's connection to his community (Yitzhak, 1998). The Druze religion calls for equality according to the laws of legitimacy written by the Druze prince Al-Amir al-Assayid from Lebanon, who gave an integrated picture of the role and status of women in society. He compared men and women with religious duties, responsibility, reward and punishment. Among other things, he arranged all personal status issues and anchored them in laws that serve as the basis for Druze personal law (Fuad Abu Zaki, April 1997). The Druze religion gave Druze women the freedom to choose and decide, and the right to choose who to marry. It also gave women the right to divorce their husbands, and gave them a strong status for dignity and equality between men and their right to participate actively in life. In other words, the Druze religion espouses equality between men and women, and the woman can serve as spiritual leader of the Druze community, and moreover, equality in inheritance (Marcel Nasser, 1997). Therefore, the status of Druze women in society and in law provides a solution to basic human rights, rights of life, equality, dignity, liberty, family and personal security. This approach places the issues of the "status of women" as issue of "human rights." (Orit Kamir, 2000). In my opinion, if the members of the community implement the Druze religious laws, the Druze society will be the most advanced society in the world. And today the world is developing an interest in feminism, and feminism is a set of beliefs and ideas belonging to a social and political movement whose goal is to achieve greater equality and freedom for women (Bell Hawkes, 2002).

## **2. The contribution of Druze women to social and cultural development**

Development and education in the Druze community are based on equality between men and women. Amongst the Druze child care and education continues until adolescence. Society plays an important role in providing services that assist women in their role and in the implementation of their duties. The society must prepare these mothers by providing information and developing their abilities in using information, and supporting them in defining their rights and obligations. All these can be done by increasing cultural awareness and education of women. The Government of Israel has made great efforts to expand the access of all children to basic educational services, while providing access to free education for all children (the Compulsory Education Law) (Salman Falah, 2000). Some of the stated goals of the education system are equality, as defined in Article 8 (2) of the State Education Law in 1953, which aims to provide

equality opportunity for every boy and a girl (Weissblat, 2006, p. 3). Al-Amir Al-Sayyid, one of the Druze Clerics of the 15th century, wrote in his commentary that the absolute equality in raising the children is that the father is responsible to educate the son and the mother will educate her daughter until the age of 15. The parents have the responsibility to tell them "words of wisdom", stories of prophets and righteous people that have high moral standards. In addition, Israel state encouraged girls' education in the Druze sector, where Druze girls' classes were opened in the early 1980s (in order to raise their level), which helped to improve the level of education in the Druze sector, and confirmed the provision of free educational services. This has led to a decrease in the rate of illiteracy and has also caused a change in the Druze society. All these factors led to a change in the Druze society regarding the daughter's leaving to school and even today, the Druze ban against women regarding leaving the village for educational purposes such as schools, high schools, colleges and universities was stopped (Yusuf Hassan, 1992). Until the 90s, the girls' departure from the village was perceived as contrary to the concepts of modesty in Druze society, but in the last two decades there has been a trend that accepts and even encourages the departure of Druze women to higher education and to work outside the village (Abbas, 2010). Since the 1980s onwards, the pressures of the Druze women's movements in Israel increased and the level of cultural awareness, developments and changes of scientific and technological development, especially the media of all kinds, has influenced cultural awareness, human rights, local and international vast aspects. These changes influenced all dimensions of the modern society and particularly the Druze community. Increasing awareness beside cultural and scientific influences affects high income levels, and the creation of new variety of professions. The social and cultural awareness increased the activity of Druze women and led to the establishment of associations of women who are working hard to make changes in the conditions of Druze women and to achieve full equality of rights between men and women (such as Eshet Hayil, a pioneer woman of a soldier etc.). All these developments, as we mentioned earlier, led to the awareness of Druze women, which in sequence led to their understanding and awareness of their rights. However, alongside those developments, some of the family's roles continue to be carried according to tradition and certain roles disappear. Thus, new dynamic roles are created, and since these roles contradict the roles that have been before, the struggle between those two attitudes is significant. But the struggle is more sensitive when it comes to the role of Druze mother in the family. Prior to the establishment of the State of Israel, she had daily housework, often with the task of raising children and helping her husband in agriculture (Yosef Hassan, 1992). The perception of role is one of the most important behavioral aspects of social situations. In the Druze society, for example, the father is expected to fund and provide all the needs of his family. A father that is not providing that, or if unemployed, will lose his status as a "head" of the family, especially after the economic and social developments and changes in the Druze community. As a result, a father that can't support his family's demands, enter into a conflict between his roles. Thus, the conflict between new couples leads to the creation of a problem that describes the issue of "social pressure regulation." Despite the transition to non-agricultural employment, and the fact that Druze men were forced to work outside the village or even work far from the village, most of the Druze remained in their villages (Brudnitz and Czernansky, 1986). The changes that took place in the Druze society led to a confrontation between men and women, and as part of the responsibility to solve this conflict the Druze man began to change some of the dominant standards. The role of Druze women today is changing. She is using more educational services and institutions such as kindergartens to raise her children and is available to new roles and new definition of motherhood. A large part of the youth community also experiencing significant changes towards total separation between the two roles and the distinction between them. When Druze women and men choose their profession in life, they will take in consideration the fact that they will have to share domestic home tasks between them. They are dealing with gaps between old and new, and mainly on the conflict between conservation of culture and unique identity and dealing with the environmental pressure resulting from modern culture (Saleh, 1999). These influences often lead to controversy among generations regarding major social issues, particularly in education, identity, values, religion and the status of women. Young Druze today has new perceptions about their status deriving from religious and economic point of view, while the affinity to the Druze community and the elders of the community is weakened. The weakening of this framework in our times can jeopardize the continued existence and future of the community (Abbas, 2010). Today, religious leaders, elders and community leaders are unable to provide answers to all the questions asked by the young people (Wiener-Levi, 2004).

### **3. Druze social norms**

Social norms in Druze society are not precise and coordinated, so it is difficult to establish clear and recognized criteria for the complexity of the social situation. For example, the manner in which certain laws, customs and traditions are compatible with scientific and technological developments in the world. There are also inherent differences between couples, for example in the area of science, culture and economy perceptions. These differences in levels leads to the difference in the way children are raised and leads to differences in the layers of Druze society (Halabi Rabah, 2003). Each society set certain standards, so it will be clear to its members what is right and what to avoid. These standards control behavior in some way, but we need to understand the unknown variables around the rules that consists social systems. Social norms are the norms and social standards that the individual follows in his life and is measured on the basis of his behavior. It is determined an acceptable and unacceptable behavior in the group and the reasons for accepting them or rejecting them and it is mainly focused on habits, customs, values and tradition. The ideas and beliefs of the Druze community represent their religiosity and their holy places, which cannot be touched and are above all else. Beside those beliefs, customs and traditions built by acts or active behavior that arose through an agreement

between the religious leaders of the community and are passed on from generation to generation (Dana, 1974). In the Druze community, values and habits are agreed upon by a group of elderly people of high religious and social status. They can also change these laws, behaviors and traditions after their have declared that publically. Their changes and amendments will be acceptable by the Druze society. But today there is a mismatch in these decisions and patterns of behavior that reflect values, customs and tradition, and therefore a group in the community began to show that they are unwilling to accept the decisions made by the religious leaders in some aspects of life. The Druze youngsters today have new perceptions about their status based on religious and economic point of view. Thus the affinity to the Druze community and elders of the community is getting weakened. The weakening of this framework in our times could endanger the continuation and the future of this community (Abbas, 2010). Religious leaders, elders and community leaders are unable to provide answers to all the questions asked by the young people (Wiener-Levi, 2004). We can conclude that the set of actions and behaviors that a person adopt are according to the rules of tradition, common values in his society, and in social interaction, so every individual in a society whether it is a man or a woman will improve their behavior according to their perceptions of each other. We can conclude that each person has different role that could create difficulties with others. If each person performs his or her duties according to what is expected of him, there will be compatibility between the roles, which leads to understanding, prosperity and success in the family and society in generally. And if not, the opposite will occur, that will cause conflict and struggle between the two sexes and thus will create Section name e.g. Druze life is conducted in a democratic spirit. That was also the case in the past. In the Druze society, the issue of the status and honor of the Druze woman constitutes a significant cultural content in maintaining the Druze social order and identity, and the respectable status accorded to her by religion, especially in the aspect of family life (Falah, 2000). In these elements the Druze woman can integrate socially, develop and influence the advancement of society in general.

## References

- Abbas, R.. *The Status of Women in Druze Society - Between Tradition and Progress*. Israel. Intelligence Heritage & Commemoration Center, Ramat Hasharon. (2010).
- Dana, V., *The Druze - ethnic group and tradition*, Ministry of Religious Affairs, Jerusalem, (1974).
- Falah, S. *The Druze in the Middle East*. The Ministry of Defence, Jerusalem. (2000).
- Fuad al-Atrash, *The Druze, Subversion, History, and Reality*, Dar al-Hakma, Samia village, (2003).
- Halabi, R. *Psychological-social aspects of Druze identity in Israel*. Tel-Aviv: Hakibbutz Hameuchad. (In Hebrew). (2003).
- Hassan, Y. *Changes in the Druze communities as a result of their integration into the Israeli security system*. Department of Geography, University of Haifa. (1992).
- Hasson, A. *Changes in Druze Education*. Download from website: <http://med.org.il/site/?author=1&paged=2>. (2011).
- Hawkes, B. *Feminism for Everyone*, Haifa: Pardes Publishing. Page 12. (2002).
- Kamir, O. *Feminism, Rights and Law, in series 'university on air'*, Tel Aviv: The Ministry of Defense, publishing (2002).
- Nodings, N. *Care and concern in education: Rule and Practice*, Hed Hahinuch, (2008).
- Rimalt, N. *Legal Feminism from Theory of Practice: The Struggle for Gender Equality in Israel and the United States*, Pardes Publishing and Haifa University, (2010).
- Salah, N. *Druze Society - Tradition vs. Progress: The Story of Julis Village*, Jerusalem: The Israel Association of Community Centers. (1999).
- Weiner Levy, N. *"I am a bird but yet not flying" - the identity of the first Druze women who applied for higher education*. Dissertation for doctoral studies in philosophy, Hebrew University of Jerusalem. (2004).
- Weissblae, A. *Data on equal opportunities in education from preschool to university*. Israeli Knesset. Download from website: <http://www.knesset.gov.il/mmm/data/docs/m01585.doc> (2006).
- Yitzhak, L. *The Druze in Israel: Historical and regional Aspects*. Download from the website: <http://www.e-mago.co.il/e-magazine/druze.htm> (1998).
- Zeller Meir, M. and Perry, P. *Teachers in Israel: Feminist Perspective*. Tel Aviv: Hakibbutz Hameuchad. (2002).
- Brewer, M. and W. Gardner. *Who Is this we. Levels of collective identity and selfrepresentations*. Journal of Personality and Social Psychology. 71(1): 83-93. (1996).
- Harpaz, Y. *Women and Education, in Patriarchal Society*, Echo of Education, (2008).



## A comparative study regarding the innovation activity of various entities, in a global perspective

Jeanina Ciurea, Suzana Demyen\*

*University “Eftimie Murgu” of Resita, Faculty of Economic Sciences, Traian Vuia Sqr. no 1-4, Resita, Romania*

---

### Abstract

Society is becoming increasingly concerned, at a global level, with research and innovation, considering also the permanent technological evolution, and the capacity of research and innovation of improving the living and working conditions of people. There are various elements that contribute to the innovation level of a country, one of these being the human factor, which is considered to be one of the most crucial elements that can generate success. Scientific and practical progress has also become a necessity for any developed or developing country, with innovating enterprises playing a very important role in determining the level of progress. The present paper aims to illustrate a comparative analysis regarding the innovation activity of various entities in several countries around the world. For this objective to be achieved, there were studies various reports and datasheets, developing conclusion based on the statistical data.

*Keywords:* innovation, enterprises, entities, research, innovative capacity

---

### 1. Theoretical framework

When analyzing literature, we note that innovation is a concept that receives an increased attention during recent years, considering not only the importance of technological evolution, but also the wellbeing of the population and its linkage to other aspects, like research and development. Some sources even consider that innovation is vital nowadays to sustainable development worldwide, emerging “as a persuasive means to enhance sustainability” (Behnam et al, 2018).

Innovation becomes an aspect which can be considered “critical to business” (Luqmania et al, 2017), especially if we refer to a long-term success, Schumpeter (Schumpeter, 1942) stating a creative destruction in the case of innovation failure.

The term “innovation” has been explained in several ways in literature, but the main ideas that could be summarized as a definition indicate innovation as “the development - based on new ideas or inventions - of new products, services, processes and methods believed to create added value for society” (Cantwell, 2017), innovation being associated mostly with technology.

Literature approaches it in terms of a “successful implementation of creative ideas”, as well as a “non-linear, complex, ambidextrous process which includes components of exploration and exploitation” (Amabile, 1996 and Rosing, 2011 in Cox, Khan, 2017).

Despite these ideas, referring to the fact that innovation is strongly connected to the development of new products or processes, and also to technological advances (Edquist, 1997, Nelson, Rosenberg, 1993), we can also identify non-technological innovation, which targets a more “soft” side of a business, taking into consideration the social aspects, development of new strategies, the focus on the human nature of an organization, summarizing all these under the concept of social innovation.

Speaking both of technological and non-technological innovation, the concept is considered as “one of the most important factors of economic growth” (Strychalska-Rudzewicz, 2015), technological change being considered to be “one of the most important single factor standing behind” this phenomenon (Czerniak, Smygur, 2017). On the other

---

\* Corresponding author.

E-mail address: s.demyen@uem.ro.

hand, the Global Innovation Index points out the concept of innovation as a factor that is both critical and supportive for the policies implemented nationwide (GII, 2016), but also of changing nature (Schwaag-Serger et al, 2015).

The basis of innovation remains the novelty of ideas, these being brought "to fruition by finding certain applications that result into new products, processes or services" (Rodriguez, Hechanova, 2014), the consequence residing in a positive evolution of the business, whether we refer to a growth in the number of customers, higher sales or better financial results.

The concept of "innovative enterprise" is also mentioned in various studies, being referred to as an „entity that in a certain period of time, adopted either products or new technologies that are "specific to the knowledge-based economy", highlighting new ideas (Băloiu, Frăsineanu, 2004, in Demyen, Ciurea, 2017).

## **2. The relationship between culture and innovation**

Countries started to become more and more concerned with research and innovation, not only in present, but starting with the year 1986, through the Single European Act. It then transformed into a policy goal in order to support the technological evolution, industry and science. Other important actions followed through the years, the two concept gaining increasing attention in the European Union especially in the year 2000, when the Lisbon strategy was established, aiming the increase of competitiveness and targeting economic growth.

According to the Global Innovation Index, 2018 edition, in 2015 the states member of the United Nations "adopted the 2030 Agenda for Sustainable Development (the 2030 Agenda) and the Paris Agreement", documents that "recognize that effective national innovation systems are key to promoting scientific and technological solutions that lead to improvement in energy efficiency systems".

Researchers thus often link innovation to culture, stating that there can be identified "a significant relationship between a nation's culture and its level of innovativeness" (Andrijauskienė, Dumčiuvienė, 2017), considering that "countries may not be able to increase their rates of innovation simply by increasing the amount of money spent on research and development or industrial infrastructure" (Shane, 1993), being necessary a strong concentration of attention upon the true values of the nation.

As stated in literature, the term "culture" is not simple, although it seems to become crucial in "various respects" (Kaasa, Vadi, 2008). It defines a specific set of fundamental values of a community, but the bearers of these values are individual members of the respective community. For an economist, culture is a description, performed by other scholars of social reality, of the most comprehensive and representative utility function of a collectivity (Fudulu, 2007).

The economic definition of culture is thus limited to the core values of a community. The sociological definition, on the other hand, includes, in addition to values recognized as a central element, and a number of other elements. Geert Hofstede (Hofstede, 2010) identifies five dimensions of the concept of culture to which there was added the aspect of indulgence:

1. power distance index
2. uncertainty avoidance
3. Individualism vs. Collectivism
4. masculinity versus femininity
5. Long term orientation vs short term orientation
6. Indulgence.

The innovation performance of countries is linked to all these cultural dimensions, but the way one or the other influences the level of innovation it differs from a case to another. Often, researchers state that low power distance cultures tend to encourage innovation, by financing inventions and emphasizing the importance of autonomy for the work of subordinates. In these cases, also creativity and novelty are considered essential.

Other authors indicate a relationship between individualism and innovation, by analyzing certain sets of parameters (Kalaycı, 2015).

According to [www.hofstede-insights.com](http://www.hofstede-insights.com), there can be determined the values for each of the 6 dimensions of the concept of culture, mentioned above. The results will be presented in table 1.

In order to achieve relevant conclusions regarding the six dimensions, we must analyze each of these individually. Thus, starting with the first dimension, the power distance, we can conclude that countries that have a score over 50 are countries that accept a certain hierarchical order, considering that this first dimension refers to the extent to which societies are equal. In the countries that score over 50 points (Belgium, Bulgaria, Greece, France, Malta, Poland, Portugal, Slovenia), we notice a high dimension, there are inherent inequalities, while in organizations, usually employees are told what to do.

Individualism states the degree of independence at both country and society level. In case that the score is stated under 50 points, as in the case of Bulgaria, Croatia, Greece, Portugal, Romania, Slovenia, we identify a collectivistic society, which promotes extended relationships and long-term commitments, focusing on family and groups.

The third dimension can be interpreted a little differently, as a high score indicates masculine societies, which promote competition, while a low score indicates a feminine society, focusing on the quality of life. We identify Italy, Poland, Ireland, Hungary as masculine societies, while Denmark, Finland, Latvia, Netherlands, have low scores from this point of view, which determines us to classify them as feminine societies.

Table 1 Scores achieved by UE 28 countries in 2018

Country	Power distance index	Individualism vs. Collectivism	Masculinity versus femininity	Uncertainty avoidance	Long term orientation vs short term orientation	Indulgence
Austria	11	55	79	70	60	63
Belgium	65	75	54	94	82	57
Bulgaria	70	30	40	85	69	16
Cyprus	*	*	*	*	*	*
Croatia	73	33	40	80	58	33
Denmark	18	74	16	23	35	70
Estonia	40	60	30	60	82	16
Finland	33	63	26	59	38	57
France	68	71	43	86	63	48
Germany	35	67	66	65	83	40
Greece	60	35	57	100	45	50
Ireland	28	70	68	35	24	65
Italy	50	76	70	75	61	30
Latvia	44	70	9	63	69	13
Lithuania	42	60	19	65	82	16
Luxembourg	40	60	50	70	64	56
Malta	56	59	47	96	47	66
Poland	68	60	64	93	38	29
Portugal	63	27	31	99	28	33
United Kingdom	35	89	66	35	51	69
Czech Republic	57	58	57	74	70	29
Romania	90	30	42	90	52	20
Slovakia	100	52	100	51	77	28
Slovenja	71	27	19	88	49	48
Spain	57	51	42	86	48	44
Sweden	31	71	5	29	53	78
Netherlands	38	80	14	53	67	68
Hungary	46	80	88	82	58	31

Source: realized by authors, according to information achieved from [www.hofstede-insights.com](http://www.hofstede-insights.com)

Uncertainty avoidance indicated the extent to which society is opened to face uncertain situations, a high level showing a pronounced preference for avoiding uncertainty. Countries like Belgium, Greece, Malta, Hungary, Spain, Romania promote rules, precision, low level of innovation.

A score above 50 in case of the fourth dimension speaks about pragmatic societies, a strong adaptability and perseverance.

As researchers state, a growing number of countries decided to develop national councils for innovation, promoting a high level of interest in implementing efficient innovation policies (Schwaag-Serger et al, 2015). As Michael Porter wrote: “National culture can substantially determine business innovation” (Porter, 2000, in Strychalska-Rudzewicz, 2015), thus we can conclude that “what differentiates one culture from another are its institutions and its ways of dealing with the variety of universal problems (Williams et al, in Cox, Khan, 2017)”.

When analyzing the results, measured through a series of indicators, we observe that there are several countries that can be considered “innovation leaders”. Often, still, a very important factor that determines the classification is represented by the income group in which the countries are included.

The Global Innovation Index, 2018 edition indicate the following situation:

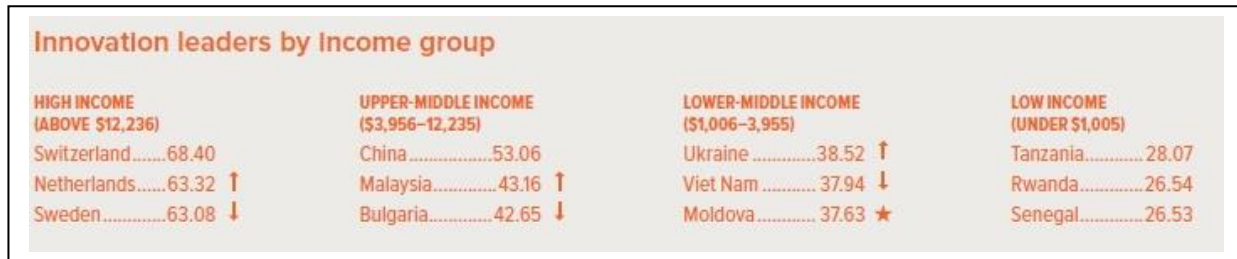


Fig. 1. Innovation leaders by income group

source: Global Innovation Index Report, 2018

When deciding, however, which country belongs in which group, there are numerous other aspects taken into consideration, the GII realizing a statistical coherence and correlations between pillars and sub-pillars. The main pillars can be mentioned as follows:

- Institutions
- Human capital and research
- Infrastructure
- Market sophistication
- Business sophistication
- Knowledge and technology outputs
- Creative outputs

While the sub-pillars target the following: political environment, regulatory environment, business environment, education, tertiary education, research and development, information and communication technologies, general infrastructure, ecological sustainability, credit, investment, trade, competition and market scale, knowledge workers, innovation linkages, knowledge absorption (GII, 2018).

### 3. The main actors in innovation projects

Innovation projects implemented worldwide assume the implication of various entities, “actors” in innovation projects (Behnam et al, 2018), each of these having different innovation capabilities, different capacities to absorb knowledge and to transfer information. Usually, entities that manage to successfully implement innovation project are rewarded with positive results, in terms of growth, customer share and profitability.

However, the results mainly differ according to the level of resources invested in the process.

According to the Global Innovation Barometer, 2018, the main actors driving innovation are:

- small and medium sized companies
- entrepreneurs and startups
- multinational companies investing in countries
- universities and research labs
- government and public authorities at national level.

But their innovation drive is different from a country to another and even from a year to another. The Global Innovation Barometer compares the results from two different years, 2014 and 2018 respectfully, the interpretation being made considering the results of a complex survey applied on representatives of the above mentioned entities, worldwide. Considering these results, it seems that currently, in the year 2018, the innovation activity is carried out at a larger scale by multinational companies and entrepreneurs or startups, and on a smaller scale by SMEs, universities, research labs or governments. We notice a great difference by comparison to the year 2014, when the innovation activity was mainly carried out by small and medium sized companies and entrepreneurs.

The results differ from a country to another, but it can be globally observed that there is a shift from small businesses to multinationals, as presented in the chart below.

Multinationals’ growing reputation as the driver of innovation is seen across the majority of countries, a decrease can be observed in case of India, South Korea and the UAE. Meanwhile, the small and medium sized enterprise face a decrease of reputation as innovation drivers, especially in European countries. According to the Global Innovation Barometer, “in parallel, in some economies where government traditionally dominated innovation, such as Turkey and South Africa, business executives now see increasing value driven by the private sector”.

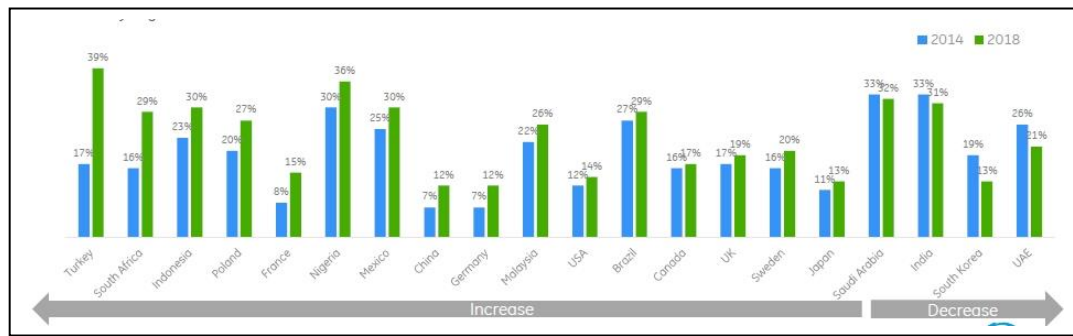


Fig. 2 Evolution of multinationals reputation in various countries

source: Global Innovation Barometer Report, 2018

In most situations, the government doesn't support innovation at a desired level, thus multinationals come as a salvation from this point of view. In some cases, traditional economies, where innovation was achieved by government until recently, we notice an increase in the private sector importance.

On the other hand, while until recently, the United States and Germany were the main innovators, the scores indicate that Asian countries like Japan and China are positively evolving and even exceed the first two, previously mentioned.

Still, despite the results acquired through studies, small and medium sized enterprises play a very important role in promoting innovation, because they are involved not only in the process of development, but also in selling the products.

They become an element of linkage between multinationals, universities and other institutes, although an additional support is necessary in order for them to carry out complex innovation projects.

Innovation can be considered as "the motor for economic change", of "importance to knowledge and learning as processes necessary for economic growth" (Cantwell, 2017).

We cannot ignore that innovation is a very important tool for technological and non-technological evolution (Ismail et al, 2014).

National culture can certainly determine the level of business innovation, while culture determines in a great measure the thinking and also the behavior of people.

Technological progress is in a great measure in a strong relationship with innovations influencing the productivity and the level of well-being of the people.

## References

- Amabile, T.M., *Creativity and innovation in organizations*. Boston: Harvard Business School Press. 1. (1996).
- Andrijauskienė Meda, Dumčiuvienė Daiva, Hofstede's cultural dimensions and national innovation level, 2017
- Băloiu Liviu, Frăsineanu Ioan, *Inovarea in economie*, Ed. Economica, Bucuresti (2004)
- Behnam Sarah, Cagliano Raffaella, Grijalvo Mercedes, How should firms reconcile their open innovation capabilities for incorporating external actors in innovations aimed at sustainable development?, *Journal of Cleaner Production* 170 (2018)
- Cantwell John Innovation and international business, *Industry and Innovation*, 24:1, 41-60, (2017)
- Cox, P. L. & Khan, R. H., Country Culture and National Innovation. *Archives of Business Research*, 5(2), 85-101(2017).
- Czerniak Jakub, Smygur Vitaliy, National Culture as a Determinant of Innovativeness, *Handel wewnętrzný*, 4(369):50-58 (tom I) (2017)
- Edquist, C., *Systems of Innovations*. Pinter, London (1997)
- Fudulu Paul, *Teoria economică a culturilor și instituțiilor. Determinarea culturală a performanțelor economice*, Ed. Universitaria, București, 2007
- Hofstede, G., Minkov, M. (2010). Long-versus short-term orientation: new perspectives. *Asia Pacific Business Review*, 16(4), 493-504.
- Kamariah Ismail, Wan Zaidi Wan Omar, Khairiah Soehod, Aslan A. Senin and Ch. Shoaib Akhtar, Role of Innovation in SMEs Performance: A Case of Malaysian SMEs, *Mathematical Methods in Engineering and Economics*, (2014)
- Kaasa Anneli, Vadi Maaja, *How does culture contribute to innovation? Evidence from European countries*, Tartu University Press, 2008
- Luqmani Adam, Leach Matthew, Jesson David, Factors behind sustainable business innovation: The case of aglobal carpet manufacturing company, *Environmental Innovation and Societal Transitions* 24, 94-105 (2017)

- Morioka Sandra Naomi, Evans Steve, de Carvalho Marly Monteiro, *Sustainable business model innovation: exploring evidences in sustainability reporting, 13th Global Conference on Sustainable Manufacturing - Decoupling Growth from Resource Use, Procedia CIRP 40*, 659 – 667, ( 2016 )
- Nelson, R.R., Rosenberg, N., Technical innovation and national systems. In: Nelson, R.R. (Ed.), *National Innovation Systems: A Comparative Analysis*. Oxford University Press, New York, pp. 3–28 (1993)
- Porter, M. E., *Attitudes, values, beliefs, and the microeconomics of prosperity*. In L. E. Harrison & S. P. Huntington (Eds.) (2000), *Culture matters: How values shape human progress*, New York: Basic Books, pp. 14–28. (2000)
- Rodriguez Raul Pelagio, Hechanova Reghina, A Study of Culture Dimensions, Organizational Ambidexterity, and Perceived Innovation in Teams, *J. Technol. Manag. Innov.* 2014, Volume 9, Issue 3
- Rosing, K., Frese, M., & Bausch Explaining the heterogeneity of the leadership-innovation relationship: Ambidextrous leadership. *The Leadership Quarterly*, 22, 5, 956-974. (2011).
- Schwaag-Serger Sylvia, Wise Emily, National Research and Innovation Councils as an Instrument of Innovation Governance - *Characteristics and challenges*, VINNOVA - Swedish Governmental Agency for Innovation Systems / Verket för Innovationssystem, (2015)
- Strychalska-Rudzewicz Anna, Cultural dimensions and innovation, *Socio- Economic Problems and the State* [online]. 13 (2), p. 59-67. (2015)
- Williams, L.K. & McGuire, S.J. Economic creativity and innovation implementation: The entrepreneurial drivers of growth? Evidence from 63 countries, *Small Business Economics*, 34, 391-412. (2010).
- \*\*\* Global Innovation Index Report, 2016
- \*\*\* Global Innovation Index Report, 2018
- \*\*\* Global Innovation Barometer Report, 2018
- \*\*\*www.hofstede-insights.com
- \*\*\* Satori, *Ethical Assessment of Research and Innovation: A Comparative Analysis of Practices and Institutions in the EU and selected other countries*, 2015

# Synergies between lean and sustainability: a literature review of concepts and tools

Ilie Mihai Taucean<sup>a\*</sup>, Larisa Ivascu<sup>a</sup>, Serban Miclea<sup>a</sup>, Mircea Negrut<sup>a</sup>

*<sup>a</sup>Politehnica University Timisoara, Piata Victoriei nr. 2, Timisoara 300006, Romania*

---

## Abstract

The concepts of lean and sustainability are increasingly used practical in companies, at all levels vertically and horizontally. Also they are used together, unitary and complementary, more and more as a single tool for reducing waste, being also an actual interdisciplinary theme of research.

Lean is one of the concepts which lead to efficiency increase of the organizations through productivity increase and in the same time with resource consumption decrease. Lean philosophy suppose that any activity without value added to be considered waste and should be eliminated. Sustainability became important with negative impact of environment changes starting with the industrial revolution (XVIII century). Research regarding sustainability highlighted the importance of responsible interaction with the environment.

The concepts of lean and sustainability started to be considered together in research literature. Studies show that there is compatibility and synergies between them, first of all, because of the waste elimination will benefit both the companies and the environment.

A literary review was carried out to search for lean and sustainability tools and their use in various domains. Relevant keywords were selected and use to find the relevant research papers. A database for paper sampling was used (Web of Science). The sample's analysis give us an overview about the distribution of the topics, ratio of journals and conferences articles, distribution over time and countries from where research came from. Also a deep evaluation was done regarding the interrelations between the two concepts and tools, and the challenges of integrated implementation of the two in companies for improving of their activity.

*Keywords:* Lean; sustainability; literature review; synergy

---

## 1. Introduction

Lean and sustainability are increasingly used concepts in companies, at all levels. They are used together, unitary and complementary, more and more as a single tool for reducing waste, being also an actual interdisciplinary theme of research.

Lean is one of the concepts which lead to efficiency increase of the organizations through productivity increase and in the same time with resource consumption decrease. Lean philosophy suppose that any activity without value added to be considered waste and should be eliminated. In research literature we can find references to a many lean tools, stating with the research of Jim Womack and Dan Jones in 1996, at Toyota Company. Lean tools appeared as a result of practical solutions found by the companies in concrete and specific situations when they have to resolve this kind of problems.

Sustainability became important with negative impact of environment changes starting with the industrial revolution in the XVIII century. Research regarding sustainability highlighted the importance of responsible interaction with the environment. In 1976 appeared the first paper with the word sustainability in the title (Stivers, R. L.: Sustainable Society: Ethics and Economic Growth, Westminster Press, Philadelphia). Studies show that those companies that take under consideration the sustainability will be the more competitive ones.

---

\* Corresponding author. Tel.: +40-744-703-894; fax: +0-000-000-0000 .  
E-mail address: ilie.taucean@upt.ro.

The concepts of lean and sustainability started to be considered together more and more in research literature. Studies show that there is compatibility and synergies between them, first of all, because of the waste elimination will benefit both the companies and the environment.

A literary review was carried out to search for lean and sustainability tools and their use in various domains. Relevant keywords were selected and used to find the relevant research papers. A database for paper sampling was used (Web of Science). The sample's analysis give us an overview about the distribution of the topics, ratio of journals and conferences articles, distribution over time and countries from where research came from. Also a deep evaluation was done regarding the interrelations between the two concepts and tools, and the challenges of integrated implementation of the two in companies for improving of their activity.

## **2. Concepts of lean and sustainability**

### *2.1. Lean concept*

Lean philosophy suppose that any activity without value added to be considered waste and should be eliminated. In research literature we can find references for many lean tools. In the research of Jim Womack and Dan Jones in 1996, at Toyota Motor Company, lean tools appeared as a result of practical solutions found by the companies in concrete and specific situations when they have to resolve this kind of problems.

Toyota Motor Company applied a new production approach called Toyota Production System (TPS) (Ohno, 1988), in order to be competitive against the American companies, in a period when Japan has resources constrains (after the Second World War). The new approach "make more with less" was later called "lean production" by Womack et al. (1990). Toyota engineers designed the TPS so that fewer and fewer resources would be required for delivering the right products at the right time at the shortest timeframes possible, by eliminating all type of waste.

Wastes were classified by Ohno (1988) in seven categories (overproduction, over processing, transports, defects, motion, inventory and waiting), and Womack and Jones (1996) defined the five Lean Principles (value, value stream, flow, pull production and pursuit of perfection). The principles aim to reduce or eliminate the 7 wastes by specify value through the customer's perspective, identify the value flow, make the value flow continuous, with no interruptions, allow the customers to pull the value along the value stream (Hallam and Contreras, 2016). The principles are cyclical and lead to continuous improvement (known as Kaizen).

Tools and techniques of LM (like JIT, TPM, VSM, pull production, 5S, Kaizen) can facilitate achieving sustainability (Vinodh et al., 2011). Organizations are competitive and achieved better results through implementation of lean concept. Companies that have adopted lean to improve their results also want to be seen as socially responsible. Sustainability is considered the new lean manufacturing frontier; this necessitates investigation of lean impact on the three sustainability dimensions: environmental, economic, and social (Martínez-Jurado and Moyano-Fuentes, 2014).

### *2.2. Sustainability concept*

Sustainability became important with negative impact of environment changes starting with the industrial revolution in the XVIII century. Research regarding sustainability highlighted the importance of responsible interaction with the environment. In 1976 appeared the first paper with the word sustainability in the title (Stivers, R. L.: Sustainable Society: Ethics and Economic Growth). Studies show that those companies that take under consideration the sustainability will be the more competitive ones.

The approach to sustainability involves economic, social, and environmental responsibilities. The balanced use of these resources without affecting the development capacity of future generations contributes to sustainable development (Izvercian et al., 2014). From an economic perspective, businesses need to improve their results. This can be achieved by increasing the level of efficiency and reducing defects. Reducing defects helps reduce costs. Reducing the waiting time is another indicator that contributes to the economic efficiency of the enterprise. Social responsibility for sustainable development takes into account society, human resources and the ability of the enterprise to engage in the development of local communities. Increasing the level of innovation has to take into account its effect on employees (reducing the number of employees, training employees to use new equipment and technologies). The company's involvement in corporate social responsibility activities is another activity of this responsibility. These activities have a number of benefits for the company: increasing the level of innovation, improving the public image, increasing the attractiveness of candidates, increasing the level of training and performance in the workplace and reducing professional risks (Izvercian et al., 2014; Băbuț and Moraru, 2018).

From the environmental perspective, industry has an important impact on the environment. This impact is mainly generated by energy consumption. Globally, energy consumption in the industrial sector accounts for over 50% of total consumption. As a result, the industrial sector has to improve its processes so that consumption is reduced and its own generation of energies is a new direction of development. After assessing current consumption levels, it can be argued that the projected growth rates follow the principles of the Paris Accord - an agreement under the United Nations Framework Convention on Climate Change (UNFCCC). From the environmental perspective, waste generated by the company must be taken into account. Reducing the amount of waste and applying the concept of circular economy



contributes to the improvement of the generation rate. The recycling capacity of the company is an important part of sustainability. Applying these principles at the enterprise level also generates a number of benefits for the company: expanding process durability by improving quality, developing new and innovative technologies, improved processes, increasing the impact of the company's image in the economic environment (Yadav et al., 2017).

Sustainability consist thus in a series of behaviors, strategies and practices aim to prevent, reduce and eliminate negative impact on the environment (Salvador et al., 2017).

### 3. The methodology of the study

A literature review was conducted with the aim to give an overview of the research in the fields of “lean” and “sustainability”, searching for the tools of these concepts which are used/propose for use in various domains. In the end we try to find if there are synergies of the two concepts as they are presented in specialized literature. A digital database for search was used: Web of Science. Although there are many digital libraries, we consider that this one give us the most valuable results for our research purpose. Relevant keywords were selected and use to find the relevant research papers: lean, sustainability, concept and concepts, tool and tools. Publications were selected by used of the keywords in: title, keywords and abstract.

The sample's analysis give us an overview about the distribution of the topics, ratio of journals and conferences articles, distribution over time and countries from where research came from. Also a deep evaluation was done regarding the interrelations between the two concepts and tools, and the challenges of integrated implementation of the two in companies for improving of their activity.

### 4. Results

Initial publications that met our search criterion using keywords: lean and sustainab\* (used for word “sustainable” and “sustainability”) were 887. We consider that these publications were too many and the study will not fully meet our aims. Out of these publications we select 184 for our study by adding in the search the keyword “tool” (or tools). We use here also an exclusion criterion: we decide to analyze only articles, proceedings and book chapter, so we exclude reviews (5) and editorial material (1). The final number of publications is now 178 and the distribution per publication type is shown in figure 1. Most publication in our analysis are articles in journals (107, around 60%) and in conferences proceedings (76, around 42.7%). As we can see from the figure 2, the time range of the publications is from 1998 to today. In 2012, Azevedo, says there is no study to show the relationship between sustainability and lean. Prior to 2012, most studies presented how sustainability benefits lean operations, and were particularly limited to environmental responsibility (Kainuma and Taware, 2006, Farish, 2009, Mollenkopf et al., 2010, Oglethorpe and Heron, 2010). For our research, we decided to include the publications prior to 2012 (27 publications, 15% of the total), as they present and analyze the concepts and propose possible tools to use in the industry applications.

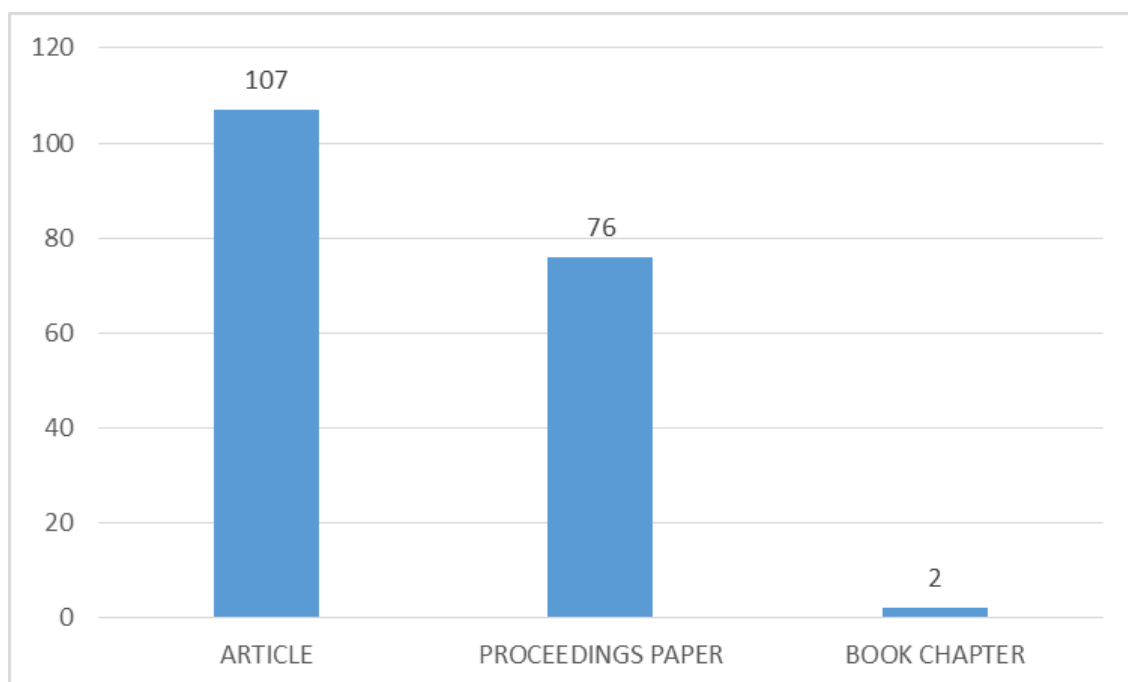


Fig. 1. Number of publications by type

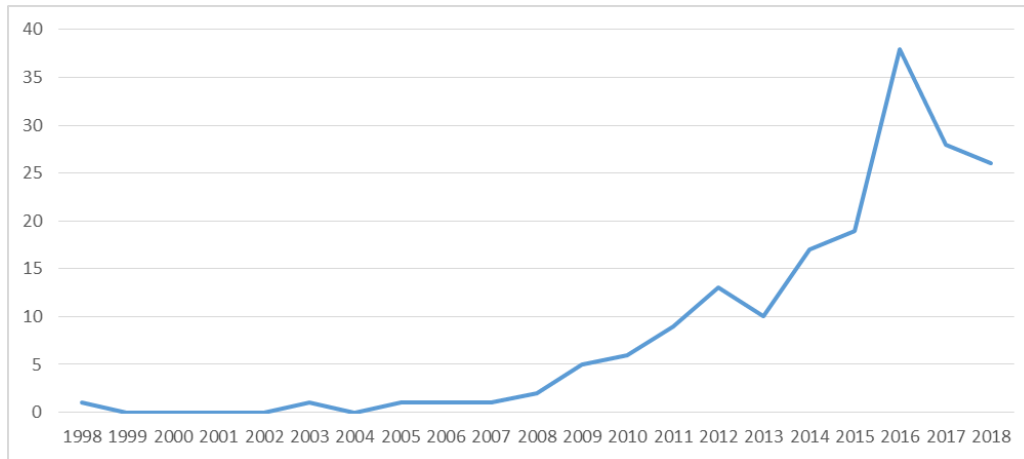


Fig. 2. Number of publications by year

As almost 85% of the papers are published since 2012, we can focus a next deep analysis on these 151 publications, which falls into Pareto rule (20/80): from 20% of the years (in our case 7 out of 21, which means 33%) we'll find 80% of the publications (151 out of 178, which means 85%). Another results here is the fact that publications peaked in 2016 (38, doubled from the previous year) and remain after 2016 higher than 2015.

Regarding the research area, there are 43 areas as seen in the figure 3 as a Pareto analysis. There are 9 areas, 21%, with 80% of the publications, starting with engineering (99) and related areas (68), environmental (23), business economics (31), and educational research (9). Here we can't exclude from our study the areas with less publications, as they are relevant to the two concepts proposed for analysis (lean and sustainability). Such areas include: energy fuels (2), food science (1), transportation (1) and urban studies (1), water resources (1) and so on.

In order to see if there are synergies between lean and sustainability, we evaluate the publications using keywords as a first analysis, and an in-depth evaluation using the concepts and tools of lean and sustainability in those publications.

First, there are a number of 144 publications which use the word "lean", respectively 129 which use the word "sustainability/sustainable", and 109 for the both words, as shown in figure 5 using a scaled Venn diagram. This is a good indication that between the two there are synergies, when more than 60% of publications use both words. But our analysis want to go beyond just the words, we looked after the tools to implement the two concepts (see table 1).

In table 1 we add (in column "Tools in publication") the number of publications with tools appearing (out of 178 publications) and number of tools appearances (in column "Tools appearances", out of 415 tools appearances).

This reveal fist that there is equilibrium of publications that mentions the two words and both words. Regarding tools appearances, there is a lean/sustainability ratio approximately of two thirds over one third. Also we find many approaches/concepts/frameworks for the two, from classical tools, to new derived tools and new tools, with works trying to integrate lean with sustainability.

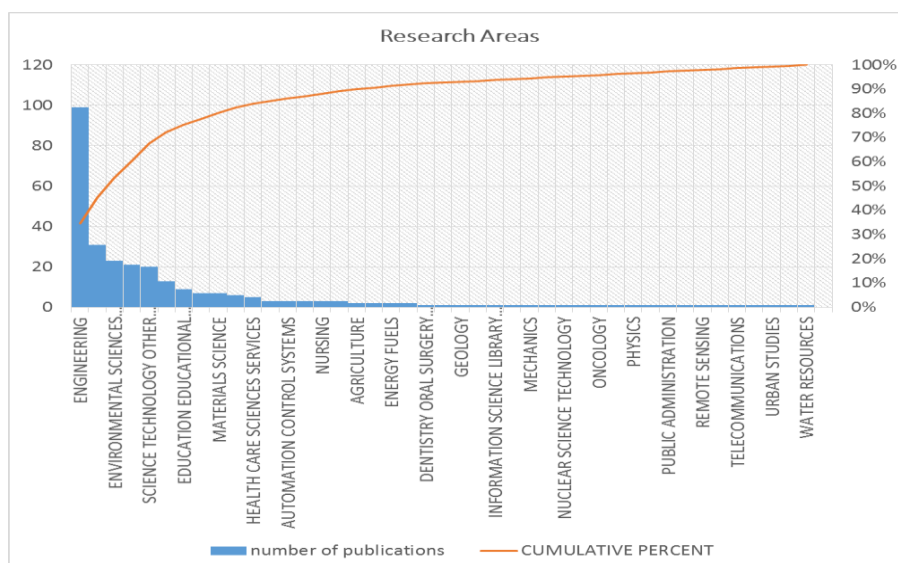


Fig. 3. Research area of publications

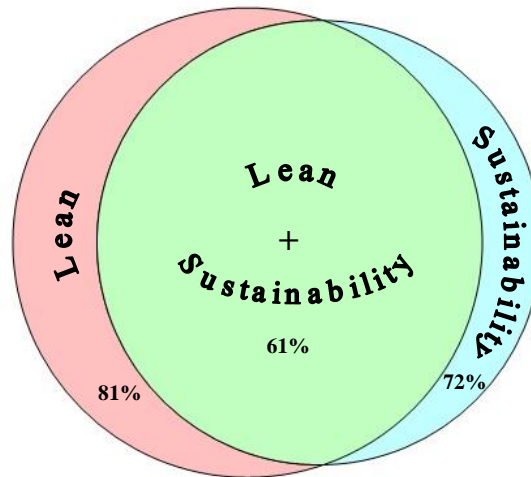


Fig. 4. Synergies of lean and sustainability

Table 1. Synergies analysis of lean and sustainability

Concepts	Keywords in publications (no. of publications)	%	Tools in publications (no. of publications)	%	Tools appearances (no. of appearances)	%
Lean	144	81	107	60	260	63
Sustainability	129	72	74	42	124	30
Lean + Sustainability	109	61	26	15	31	7

Regarding lean, the VSM tool (Value Stream Mapping) appear the most (34), followed by LSS (Lean Six Sigma and Six Sigma with 21 appearances) and 5S. Regarding sustainability, there is a larger number of different concepts, variation of concepts, with a most frequent tool LCA (Life Cycle Assessment 8 times), followed by eco-design/sustainable design (5).

There is a generous number of common/integrative tool for lean and sustainability (31) and many other studies try to put together a framework/methodology to use the two concepts in order to be successful. We can mention latest studies proposals (in the last 3 years, 2018-2016): LIMSSI (Lean-Integrated Management System for Sustainable Improvement, Souza and Alves, 2018), Lean-Sustainable Indicators Model (Isa et al., 2018), GELPM (Green Embedded Lean Production Model, Fu et al., 2017), LSS-EnMS (Lean Six Sigma Energy Management System, Mkhaimer et al., 2017), Agility-Sustainability Criteria model (Singh and Vinodh, 2017), Lean and Green SCM and LGrSCM (Colicchia et al., 2017 si Li and Found, 2016), Lean and Green House (Verrier at all, 2016), LARG Index (Lean, Agile, Resilient, Green Index, Azevedo et al., 2016), LCA-VSM (Life Cycle Assesment VSM, Vinodh et al., 2016).

## 5. Conclusions

The concepts of lean and sustainability are increasingly used in companies, more and more together, unitary and complementary, as a single tool for reducing waste. Studies showed that there is compatibility and synergies between them, first of all, because of the waste elimination will benefit both the companies and the environment.

A literary review was carried out to search for lean and sustainability tools and their use in various domains. Relevant keywords were selected and use to find the relevant research papers. A database for paper sampling was used (Web of Science). The sample's analysis gives us an overview about the distribution of the topics, ratio of journals and conferences articles, distribution over time and countries from where research came from. Also a deep evaluation was done regarding the interrelations between the two concepts and tools, and the challenges of integrated implementation of the two in companies for improving of their activity to be successful in a dynamic and competitive economy.

## Acknowledgements

This work was supported by research grants PCD-TC-2017.

## References

- Azevedo, S.G., Carvalho, H., Cruz-Machado, V., LARG index: A benchmarking tool for improving the leanness, agility, resilience and greenness of the automotive supply chain, *Benchmarking: An International Journal*, 23(6), 1472-1499 (2016).
- Băbuș, G.B., Moraru, R.I., Occupational risk assessment: imperatives for process improvement, *Quality - Access to Success*, vol. 19(166), 133-144, (2018).
- Colicchia, C., Creazza, A., Dallari, F., Lean and green supply chain management through intermodal transport: insights from the fast moving consumer goods industry, *Production Planning & Control*, 28(4), 321-334, (2017).
- Farish, M., Plants that are green: Toyota's lean manufacturing, *Engineering and Technology*, vol. 4 (3), 68-69, (2009).
- Fu, X., Guo, M., Zhanwen, N., Applying the green Embedded lean production model in developing countries: A case study of china, *Environmental Development*, 24, 22-35, (2017).
- Hallam, C., Contreras, C., Integrating lean and green management, *Management Decision*, vol. 54(9). 2157-2187, (2016).
- Isa, R., Emuze, F., Das, D., Awuzie, B.O., Modeling a transformational route to infrastructure sustainability in South Africa, *Built Environment Project and Asset Management*, 8(2), 147-159, (2018).
- Izvercian, M., Ivascu, L., Potra, S., Enterprise Sustainability Management: An Emergent Approach and Research Imperatives, *Crafting Global Competitive Economies: 2020 Vision Strategic Planning & Smart Implementation, 24th IBIMA Conference*, ISBN 978-0-9860419-3-8, Milano, Italia, 440-449, (2014).
- Kainuma, Y., Tawara, N., A multiple attribute utility theory approach to lean and green supply chain management, *International Journal of Production Economics*, vol. 101 (1), 99-108, (2006).
- Li, A.Q., Found, P., Lean and Green Supply Chain for the Product-Services System (PSS): The Literature Review and A Conceptual Framework, *Procedia CIRP*, 47, 162-167, (2016).
- Martínez-Jurado, P.J., Moyano-Fuentes, J., 2014. Lean management, supply chain management and sustainability: a literature review, *J. Clean. Prod.* 85, 134e150, (2014).
- Mkhaimer, L.G., Arafeh, M., Sakhrieh, A.H., Effective implementation of ISO 50001 energy management system: Applying Lean Six Sigma approach, *International Journal of Engineering Business Management*, 9, 1847979017698712, (2017).
- Mollenkopf, D., Stolze, H., Tate, W., Ueltschy, M., Green, lean, and global supply chains, *International Journal of Physical Distribution and Logistics Management*, vol. 40 (1/2), 14-41, (2010).
- Oglethorpe, D., Heron, G. (2010), Sensible operational choices for the climate change agenda, *International Journal of Logistics Management*, vol. 21 (3), 538-557, (2010).
- Ohno, T., *Toyota production system: beyond large-scale production*, Portland, OR: Productivity Press, 1988.
- Salvador, R., Piekarski, C.M., Francisco, A.C.D., Approach of the Two-way Influence Between Lean and Green Manufacturing and its Connection to Related Organisational Areas, In *International Journal of Production Management and Engineering*, Vol. 5, No. 2, pp. 73-83, (2017).
- Singh, A.K., Vinodh, S., Modeling and performance evaluation of agility coupled with sustainability for business planning, *Journal of Management Development*, 36(1), 109-128, (2017).
- Souza, J.P.E., Alves, J.M., Lean-integrated management system: A model for sustainability improvement, *Journal of Cleaner Production*, 172, 2667-2682 (2018).
- Stivers, R.L., *Sustainable Society: Ethics and Economic Growth*, Westminster Press, Philadelphia, (1976).
- Verrier, B., Rose, B., Caillaud, E., Lean and Green strategy: the Lean and Green House and maturity deployment model, *Journal of cleaner production*, 116, 150-156, (2016).
- Vinodh, S., Arvind, K.R., Somanaathan, M., Tools and techniques for enabling sustainability through lean initiatives, *Clean Technologies Environmental Policy*, 13, (2011).
- Vinodh, S., Ruben, R.B., Asokan, P., Life cycle assessment integrated value stream mapping framework to ensure sustainable manufacturing: a case study, *Clean Technologies and Environmental Policy*, 18(1), 279-295, (2016).
- Womack, J.P., Jones, D.T., Roos, D., *The Machine that changed the world*, Rawson Associates, New York, (1990).
- Womack, J.P., Jones, D.T., *Lean Thinking - Banish Waste and Create Wealth in Your Corporation*, New York, Free Press, (1996).
- Yadav, O.P., Nepal, B.P., Rahaman, M.M., Lal, V., Lean implementation and organizational transformation: a literature review, *Engineering Management Journal*, vol. 29 (1), 2-16, (2017).

## Study regarding optimum functionality of analyzers (motor and optic) increasing the precision and efficiency in ball transmission

Ioan Stelescu \*

*University of Petroșani, University street no. 20, Petroșani, 332006, România*

---

### Abstract

The improvement of the functionality of the analysers – especially the kinaesthetic one and respectively the optic one – shall ensure the activity of the sensors and of the perceptions by refining the sensitivity thresholds and lead to the increase of efficiency and precision in passing the ball and nevertheless the capacity to solve the changing tasks of the game nowadays.

Sensory perception specific to each player (in our case) the visual analyser gives the player fast information regarding the situation on the pitch

*Keywords:* sensory receptivity, increase of efficiency, increase of precision, technical procedures, ball passing

---

### 1. Motivation of choice

We have started from the idea that if the improvement of the functionality of the analyser, namely the kinaesthetic and the optic analysers, ensures the activity of the sensors and the perceptions by tuning the sensitivity thresholds it will certainly lead to the increase of the efficiency and the precision of passing and consequently of the ability to solve forever changing tasks the actual game keeps bringing forward.

The improvement/teaching of neuromuscular control shall be reflected in superior efficiency indexes of the technical procedures of ball passing at the level of the inferior and respectively the superior limbs and the head.

### 2. Purpose of the research

It can thus be said that sensory perception specific to each player (in our case) the visual analyser gives the player fast information regarding the situation on the pitch. The receipt of the visual information by the Central Nervous System (CNS) creates a basis for the decision to be taken and sends the command to the muscle of the inferior limbs in order to carry out the hit toward the goal or pass the ball. This sensory receptiveness is manifested as well in relation to the information from other analysers of the human body (muscular sensation, hearing and vestibular sensations).

### 3. Research methods

In order to create the present paper, the following methods were used:

- The bibliographic study;
- Direct observation;
- The graphical method – used to express a large number of data;
- The case study;
- The “transversal” experimental method where the change of different variables for an athlete was followed during a specific moment.

---

\* Corresponding author. Tel.: +4.025.454.2581 int.170  
E-mail address: i\_stelescu@yahoo.com

- The statistical – mathematical method was used to determine and calculate the following indicators while analysing the data obtained through precise measurements:

$M_0$	- module
$M$	- median
$\overline{X}$	- arithmetic mean
$W$	- amplitude
$A_m$	- average deviation
$S$	- standard deviation
$CV$	- the coefficient of variability

The significance between the lines of data for correlated samples

### Content of research

The present research was carried out experimentally and proposes to study the precision of ball passing and its role during technical and tactical training for 14-16 year olds junior football players considering a cycle of 284 football training sessions, respectively between 06.07.2017 - 17.06.2017.

The materials used for the experiment were:

- records
- timer
- flags
- pickets
- medicine balls
- footballs

The venue for the experiment was and the football pitch and the gymnasium of the Satu Mare Sports High School.

### 4. Researched human subjects

In order to perform the experiment, researches were carried out on a number of 18 students (16 field players and 2 goalkeepers) who are part of the junior group of players born in 2003 of the Satu Mare Sports High School. They all have 4 years of experience in playing football.

During the research, students have shown a really responsible behaviour and deep understanding of the objectives considered for their training, creating therefore an optimum and correct motivation regarding the role of the technical procedures used during the football game. Data and appreciations regarding the effort capacity of each subject were recorded in different training period. The health of the students who took part in the experiment was quite good.

#### Control tests

The research makes use of 7 control tests which assess the level of specific skills required for the game of football.

#### Technical tests for junior players:

##### ❖ *Precision ball passing*

- ball in one place: a corridor of 3m wide and 25m long is drawn; each player will be allowed 5 runs; the length is measured from the kicking spot to the spot where the ball touches the ground for the first time; the number of successful trials is recorded; the number of trials where the ball is out of the bounds of the corridor do not count.

##### ❖ *Shooting 8 balls toward the goal from a distance of 16 m / time unit*

- the maximum number of shots at the goal / time unit (the goal divided vertically in 3); 8 shots are carried out – 3 consecutive shots in the sides and 2 in the centre.

##### ❖ *Technical set - taking over – dribble – shoot from 16m / time unit*

- the starting point is at 9 m in front of the 16 m line; the player receives a ball at 1 m from the first picket after which he starts while leading the ball between 3 pickets placed every 3 meters and will finish by shooting toward the goal from the 16 m line; each player shall have 2 trials; the time passing from the start to when the ball crosses the goal line shall be recorded, shoots in which the balls touches the ground before crossing the goal line shall not be taken into account; the best trial is recorded.

##### ❖ *8 ball shooting toward the goal, hitting the ball with the head while jumping from 11 m*

- the goal is vertically divided in 3; the player has the ball thrown having to score as follows: 3 consecutive goals in the sides and 2 in the centre; only the successful trials are marked; the trials in which the ball hits the ground before crossing the goal line are not taken into account

##### ❖ *Technical tactical set*

- the following actions are performed by the player successively and with speed: jits the ball from the corner, with the right foot toward the penalty spot (11 m) (4 m radius), runs to the corner of the surface on the length of which there are 4 balls placed at a 2 m distance; running he shoots all 4 balls with his left leg; he then runs toward the other side of the pitch where he shoots the ball from the corner toward the penalty spot (11 m) (4 meters radius circle) runs again toward corner of the penalty surface on the length of which there are 4 balls and shoots them with his right leg;

- the time required for the execution of the set and the successful trials (namely the kicks which manage to send the ball into the net and the ball does not touch the ground before it crosses the goal line) are marked down.

#### ❖ Precision ball passing

Considering the carrying out procedure – number of successful executions in the established space – the coordination skill was tested for the able foot, as well as the strength at the level of the inferior limbs muscles.

**Figure 1**, brings forward the average value is 2.06 successful trials for initial testing and 3.22 for final testing the progress being therefore of 1.16 executions.

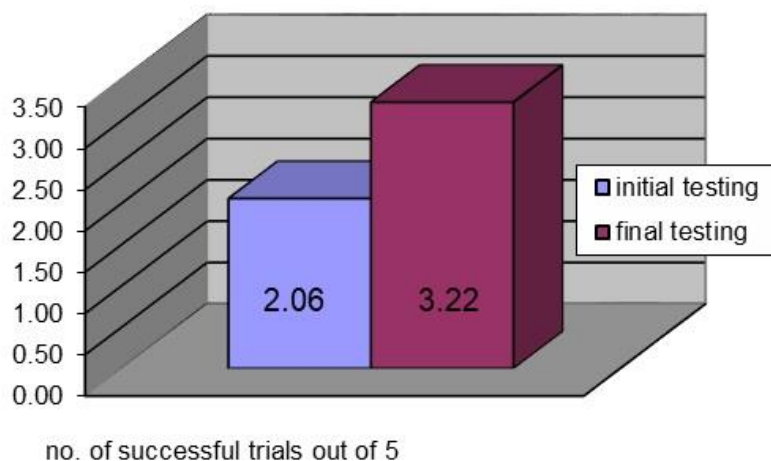


Fig. 1. Precision ball passing

The vertical analysis of tables 1 and 2 shows individual values comprised between 1 and 5 executions, while the horizontal analysis highlights the continuous increase for almost every member of the group.

The statistical mathematical indicators show an average of 3.22 executions for the final testing the standard deviation being  $\pm 1.17$ , while the coefficient of variability highlights a lack of homogeneity (36.21%).

The determination of  $t$  confirms that the differences are 95 – 99% significant.

#### ❖ Shooting toward the goal from 16 using 8 balls / time unit

Considering the procedure of the trial – number of executions during a time unit / number of successful executions in the goal – the strength development level of the muscles of inferior limbs as well as the coordination skills of the able foot and the sense or responsibility for the shoots were tested.

The vertical analysis of tables 1 and 2 represents the number of executions / time unit, individual values comprised between 15s and 13.5s, while the horizontal analysis highlights a continuous increase of the performances together with the increase in the number of successful trials. The diagram presented in Figure 2 highlights the increase of the average of the group for trials with 2.79 executions, respectively 3.50 to 6.31 executions and a drop in the time of the execution of the 8 shots with 5s respectively 15.0s to 14.5s.

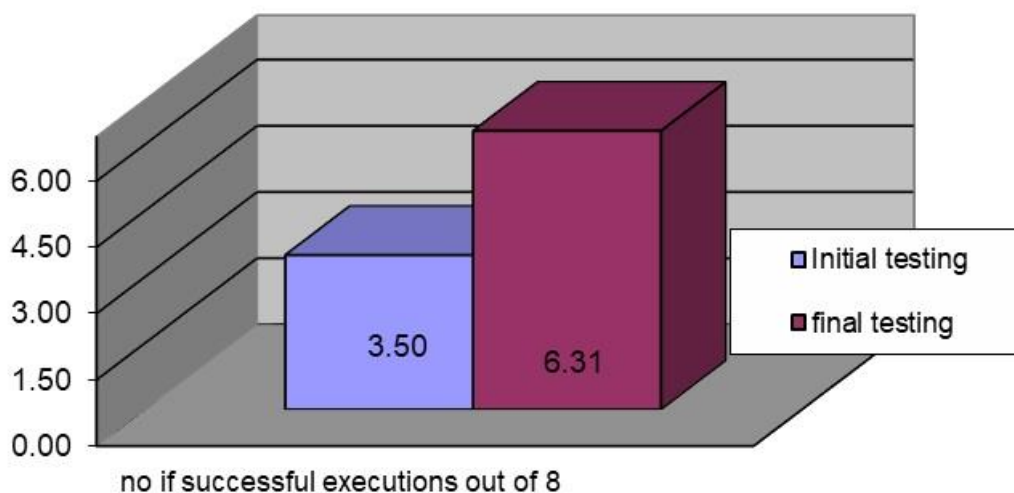


Fig. 2. Shots toward the goal with 8 balls from 16 m / no. of successful executions



The statistical indicators of the number of successful executions / time unit represents an average of 14.54s, while the standard deviations represents a normal distribution of over 68%, the coefficient of variability indicating a higher homogeneity during executions, namely with 6.59%, while the average of successful trials is 6.31, and the standard deviation is ( $\pm 1.45$ ) being normal and comprising 68% of the cases, the coefficient of variability indicating a lack of homogeneity, namely 22.98%.

$t$  is calculated and determined and confirms that the differences are significant and 95-99% sure.

#### ❖ Technical Set

The execution of the trial tested the coordination skills of the able foot and the sense of responsibility of the shoot toward the goal under time pressure.

Vertically analysing table 1 it results that out of 16 players 4 did not manage to send the ball in the goal from 16 m in order for the ball to fall behind the goal line.

The vertical analysis of table 2 brings forward individual values comprised between 4.7s and 6.1s, while the horizontal analysis highlights a continuous increase of performances

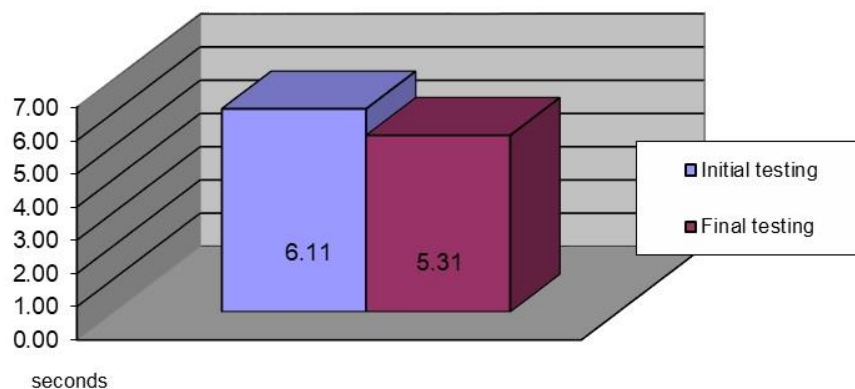


Fig. 3. Technical Set

The diagram presented in Figure 3 highlights a drop in the execution time from 6.11s to 5.31s. the statistical indicators highlight an average of 5.3s, while the standard deviation ( $\pm 0.51$  s) presents a normal distribution, the coefficient of variability bringing forward a high homogeneity namely of 9.57%.  $t$  being determined and calculated confirms that the differences are significant being 95-99% sure, the risk of failure being comprised between 1-5%.

#### ❖ Shots toward the goal using 8 balls, hitting the ball with the head while jumping from the penalty spot (11 m)

The execution of the trial puts to a test the coordination skills at the level of the head as well as the development of the strength at the level of the muscles of the inferior limbs. The analysis of the diagram presented in figure 4 highlights average values of 3,81 for successful executions for the initial testing and respectively 6.19 for the final testing, the progress being of 2.38 successful executions

The vertical analysis of table 2 brings forward individual values comprised between 4 and 8 executions, while the horizontal analysis highlights a continuous increase for 15 players.

The statistical indicators bring forward a standard deviation with normal values which comprises 68% of the cases, the calculated and determined coefficient of variability highlighting an average of 17.91%.

The calculated  $t$  confirms that the differences are significant being 95-99% sure

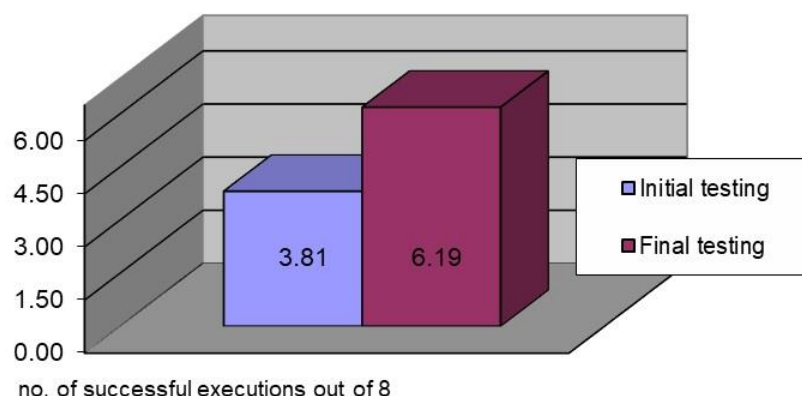


Figure 4. Shots toward the goal using 8 balls, hitting the ball with the head while jumping from the penalty spot (11m)



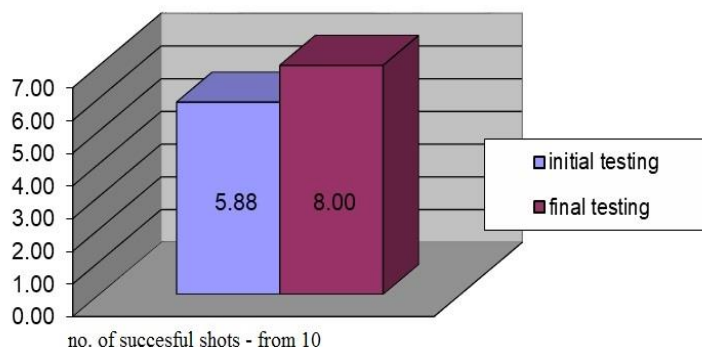


Fig. 5. Technical tactical set / no. of successful executions

#### ❖ The technical tactical set

The model of the execution – number of executions in a time unit / number of successful executions puts to a test the level of the strength as stamina at the level of the muscles of the inferior limbs, of ambidexterity at the level of the inferior limbs and the sense of responsibility of the goal kick.

The vertical analysis of table 2 brings forward the number of executions / time unit, individual values comprised between 33.6s and 43.2s, while the horizontal analysis highlights a continuous increase of performances together with the increase of successful executions.

The diagram presented in **Figure 5** highlights an increase of the average of the group for trials with 2.12 executions respectively from 5.88 to 8.00, and a drop of the time of execution from 39.07s to 38.13s. The statistical indicators for the number of successful executions / time unit presents an average of 38.1, the standard deviation presents a normal distribution of over 68% while the coefficient of variability indicates a homogeneity of 7.91% and for the successful executions the average is 8.00 the standard deviation being normal comprising 68% of the cases and the coefficient of variability indicating an average homogeneity of 16.46%.

The calculate and determined value of  $t$  confirms that the differences are significant for 95-99% of the cases the risk of failure being comprised between 1 and 5%.

## 5. Conclusions

- The present study is part of a series of searches carried out by specialists in the field in order to increase the efficiency of the training session, the accuracy in passing the ball, its contribution to the training of future football player taking into consideration the requirements imposed by the modern football game.
- The values obtained following the researching procedures for precision ball passing, hitting the ball with the head (for players) as well as sending the ball with precision at a distance and throwing the ball with precision at a distance (for goalkeepers), have recorded a continuous increase of performances compared to the initial testing.
- the values obtained for the technical set, the technical tactical set, as well as for the goal shooting from 16 m, are continuously increasing with the consequent reduction of the time necessary for successful executions.
- The statistical – mathematical indicators reflect a standard deviation with a normal distribution, comprising over 68% of the cases, the coefficient of variability highlighting the high and medium homogeneity for most of the trials, while the value of  $t$  highlights that the differences between the two executions are certain in 95-99% of the cases with only 1-5 % risk of failure.

## 6. Recommendations

- In order to train the visual-kinaesthetic interaction we propose the use of means for sending the ball with precision, in order to improve target hitting, as well as the use of special methods to improve the clarity of the visual field in the game (both between the games as well as during the said game).
- The existence of a series of external stimuli for guiding the movement in order to create the optimum conditions for the specific target practice exercises, through visual appreciation of the distance and the adaptation of the visual receptivity to the specific actions of the game.

## References

- Apolzan, D., 2000, *Fotbal 2010*, FRF, Bucharest.
- Bompa, T., 2002, *Periodizarea: Teoria și metodologia antrenamentului*, Bucharest, C.N.F.P.A. Ex Ponto.
- Bota C., Prodescu, B., 1997, *Fiziologia Educației Fizice și Sportului, Ergofoziologie*. Rm.Vâlcea, Ed. Antimivireanul.
- Cernaianu, C., 2001– *Fotbal – Manualul antrenorului profesionist*, Bucharest, Ed.Rotech Pro
- Cojocar, V., 2002, *Fotbal de la 6 la 18 ani-Metodica pregătirii*, Bucharest.
- Dragnea, A. si colab.,2000, *Teoria educatiei fizice si sportului*, Bucharest, Cartea scolii Publishing.

- Dragnea, A., Bota, A., 1999, *Teoria activităților motrice*, Bucharest, Didactică și pedagogică, R.A. Publishing.
- Dragnea, A., 1990, *Teoria și metodică dezvoltării calităților motrice*, Bucharest, Centrul de multiplicare ANEFS, *Enciclopedia Universalis*, Editeur a Paris, France.
- D'Ottavio S., 1996 "*Individuazione, selezione e promozione del talento giovanile*", da Atti del convegno: "L'attività Giovanile nella Società professionistiche", Firenze-Centro Tecnico do Coverciano.
- D'Ottavio S., 2003 *Atti del Corso di Laurea Specialistica in Scienze e Tecnica degli Sport*, Università Tor Vergata, Rome.
- Epuran, M., Holdevici, I., Tonița, F., 2001, *Psihologia sportului de performanță*, FEST Publishing, Buchar Epuran, M., 2005.- *Metodologia cercetării activităților corporale*, FEST Publishing., Bucharest
- Manno, R., 1992, *Les bases de l'enrtaînement sportif*, Paris, Edition Revue E.P.S.
- Miu, Ș., Valea, F., 2002 "Fotbal - specializare" - România de Mâine Foundation Publishing, Bucharest
- Motroc I., Motroc F., 1996, *Fotbalul la copii și juniori*, E.D.P., Bucharest.
- Neța, Gh., Popovici, C., "Fotbal 2000" – JRC Publishing, Turda, 2000
- Popovici, C., "Fotbal - tehnica jocului" – ICIPIAF Publishing, Cluj - Napoca, 1995
- Popovici, C., 2005 *Fotbal copii și juniori*, Cluj Napoca, Napoca Star Publishing.
- Rigal, R., 2006, *Educación motriz y educación psicomotriz en preescolar y primaria*. Barcelona:INDE.
- Rădulescu, C., 2000, "Fotbal - principii, metode, mijloace." – Sarmis Publishing, Cluj-Napoca.
- Rădulescu M., Cojocaru V., *Ghidul antrenorului de fotbal. Copii și juniori*. - Axis Mundi Publishing, Bucharest, 2003.
- Stelescu I., 2011, Caracteristici psiho-sociale în jocul de fotbal, Universitas Publishing, Petroșani.
- Stelescu I., 2012; Probleme ale capacității psihomotrice în fotbal, Focus Publishing, Petroșani.
- Venglos J., 2004, Curs U.E.F.A., Antrenorul nr. 3, F.R.F., Școala Națională de Antrenori, Bucharest, pp. 12-15.est

## Strenght and distance in relation with intensity of throwing, running and jumping in youth football

Stelescu Ioan\*

*University of Petroșani, University street no. 20, Petroșani, 332006, România*

---

### Abstract

The physical performance of a football player mainly consists in speed / moving speed and the execution of technical elements as well as in the availability of the subject to repeat as many times as possible during a game the actions and high intensity movements.

The strength of the protractor muscles stagnates or regresses during this period which implies the large and varied use of strength training exercises destined for this group of muscles as well as those groups used while moving and performing technical movements (inferior limbs).

*Keywords:* development, quality of movement, precision of movement, strength, muscles

---

### 1. Motivation of choice

Having carried out multilateral researches on different samples in terms of age and level we have come up to valuable conclusions which allow the practitioners to reconsider some of their methodological procedures, their objectives and even the way they are realised.

We have always considered the development of fine motor skills as very important as they ensure harmonious physical development on one hand and the development of strength necessary for the training on the other.

Any football player holds a so called sensorial perception, if the interaction between the visual analyser and the fine motor effector in football players is flawed and especially if the visual analyser of the athlete is not trained and it is not prepared to perform competition specific activities (i.e. the estimation of the distance, visual acuity, estimation of the speed) then, naturally, there is no chance for a high quality game to occur.

### 2. Purpose of the research

Conditional skills are in direct dependence on the stamina and are based on metabolic efficiency of muscles and other systems such as the cardiovascular, respiratory or nervous systems. The conditional aspects depend on the fine motor skills: force, speed, stamina, being nevertheless tested in the present paper. Coordinative skills imply the appearance with the individual of alertness, cleverness, ingenuity, reaction speed, focus capacity and attention transfer, movement precision (spatial, temporal, dynamic) and their rationalisation from a biomechanically point of view.

The study tries to highlight the fact that in the present phase football playing organised scientifically contributes largely to the development of morality, willingness and character. The methodological analysis verifies that the principles are respected and especially tries to establish the optimum articulation of methods, techniques and researching instruments into one efficient strategy.

#### 2.1. Researching hypotheses

1. Continuously assessing the fine motor skills of football players corroborated with the creation and the implementation of training tests which we prepared a continuous adjustment of the fine motor skills shall be performed.

2. The permanent monitoring of the development level of the fine motor skills specific to football combined with the creation of training tests for each step and phase of the specific training leads to getting superior results during competitions.

---

\* Corresponding author. Tel.: +4.025.454.2581 int.170  
E-mail address: i\_stelescu@yahoo.com

### 3. Research methods

In order to create the present paper, the following methods were used: the bibliographic study; direct observation; the graphical method – used to express a large number of data; the case study; the “transversal” experimental method where the change of different variables for an athlete was followed during a specific moment. The statistical – mathematical method was used to determine and calculate the following indicators while analysing the data obtained through precise measurements:  $M_0$  - module,  $M$  - median,  $\bar{X}$  - arithmetic mean,  $W$  - amplitude,  $A_m$  - average deviation,  $S$  - standard deviation,  $CV$  - the coefficient of variability. The significance between the lines of data for correlated samples.

#### 3.1. Content of research

Either considering the competitions between young players or adult players independent on their level, the physical performance of a player consists in fastness / speed and the execution of technical elements such as the availability to repeat as many times as necessary during a game the high intensity actions and movements.

Therefore, a process for training – development of training sessions directed toward the stimulation of organic functions, the neuromuscular quality and the growing processes need to contain exercises which will allow the junior player to train his strength, stamina and speed.

The materials used for the experiment were: records, timer, flags, cone markers, medicine balls, footballs.

### 4. Researched human subjects

In order to perform the experiment, researches were carried out on a number of 18 students (16 field players and 2 goalkeepers) who are part of the junior group of players born in 2003 of the Satu Mare Sports High School. They all have 4 years of experience in playing football.

During the research, students have shown a really responsible behaviour and deep understanding of the objectives considered for their training, creating therefore an optimum and correct motivation regarding the role of the technical procedures used during the football game. Data and appreciations regarding the effort capacity of each subject were recorded in different training period. The health of the students who took part in the experiment was quite good.

#### ❖ 30 m dash test

This type of test highlight the speed of young players expressed in m/s, being in close accordance to the explosive strength at the level of the inferior limbs. The horizontal analysis of tables 1 and 2 the results obtained by the subject highlight a continuous evolution, but speed being mainly a motor skill determined by genetics, the improvement and variation of speed is not spectacular.

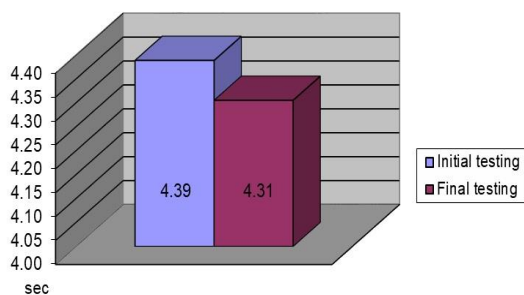


Fig. 1. 30 m dash run

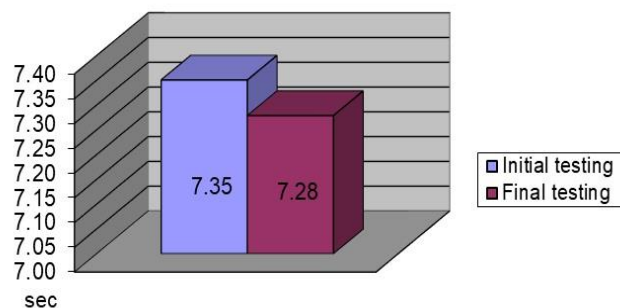


Fig. 2. 2000 m endurance run

The standard deviation ( $\pm 0.19$  or rounded  $\pm 0.2$ ) is normal, comprising more than 68% of the cases, in our case the average is  $4.3 \pm 0.2$  s, namely the values situate between 4.1 s and 4.5 s deviate from the average with the standard determined and calculated for the group; coefficient of variability highlights a large homogeneity of 4.33%.

The vertical analysis of the table highlights individual values observed during the final testing comprised between 4.0 s and 4.6 s.

The determination and calculation of  $t$  confirms that the differences are significant being 95-99% certain.

#### ❖ 2000 m endurance run test

The execution of the test highlights the aerobic endurance ability of the body.

The horizontal analysis of tables 1 and 2 highlight that the results obtained by the subjects are under constant evolution.

The dynamic of the average of the group (see figure 2) increases from 7.35 to 7.28 with a progress of 7 s. the statistical – mathematical indicators highlight a standard normal deviation ( $\pm 12$  s), comprising over 68% of the assessed cases, the coefficient of variability recording a high homogeneity of 1.71%.

The vertical analysis of tables 1 and 2 highlight individual values during the final testing comprised between 7.05 and 7.50.

The determination and calculation of  $t$  confirms that the differences are significant being 95-99% certain.

#### ❖ Penta jump

This test highlights the explosive strength (expansion strength) of the inferior limbs. The dynamic of the group average (see figure 3) increases from 11.96 during the initial testing to 12.20 m during final testing, namely a progress of 24 cm. the statistical indicators highlight a standard normal deviation ( $\pm 40$  cm), comprising 68% of the cases tested, the coefficient of variability recording a homogeneity larger than 3.29%.

The vertical analysis of tables 1 and 2 from annex 1 respectively 2, highlight individual values during the final testing comprised between 11.45 and 12.94 m.

The determination and calculation of  $t$  confirms that the differences are significant being 95-99% certain.

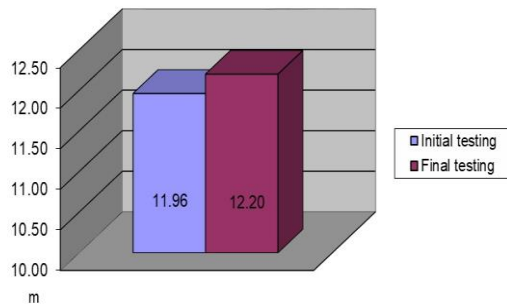


Fig. 3. Penta jump

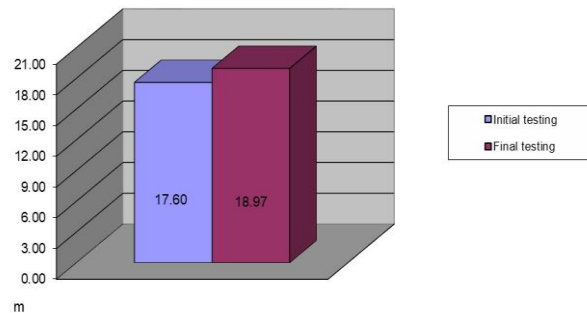


Fig. 4. Throwing the 2 kg medicine ball

#### ❖ Throwing the medicine ball from a static position to a distance using both hands above the head

The test highlights the expansion strength of the superior limbs, testing the level of the strength and speed of the muscles of the superior limbs.

The vertical analysis of tables 1 and 2 from annex 1 respectively 2, highlight individual values during the final testing comprised between 16.80 – 23.40 m, while the horizontal analysis highlights a continuous individual evolution of each member of the team.

The distribution of individual values presents an asymmetric distributions compared to the group average, highlighting both the weak results as well as the results better than the group average.

The statistical mathematical indicators highlight an average of 18.97 m, the standard deviation presents a normal distribution of over 68%, while the coefficient of variability brings forward a homogeneity of 9.63%.

The determination and calculation of  $t$  confirms that the differences are significant being 95-99% certain.

#### ❖ Hitting the football while jumping from a stative position

The model of the test – maximum number of executions / time unit – follows to assess the development level of the strength as speed of the muscles of inferior limbs.

The analysis of the diagram presented in Figure 5 highlights average values of 24.83 executions for initial testing and respectively 27.78 during the final executions, the realised progress being of 2.95 executions.

The vertical analysis of tables 1 and 2 brings forward individual values comprised between 24 – 30 executions, while the horizontal analysis highlights a continuous increase for each member of the group.

The statistical mathematical indicators bring forward an average of  $\bar{x}=27.22$  executions during the final testing, the standard deviations presenting normal values which comprise more than 68% of the cases, the coefficient of variability presenting an homogeneity higher than 6.97%.

The determination and calculation of  $t$  confirms that the differences are significant being 95-99% certain, the risk of failure being comprised between 1 – 5%.

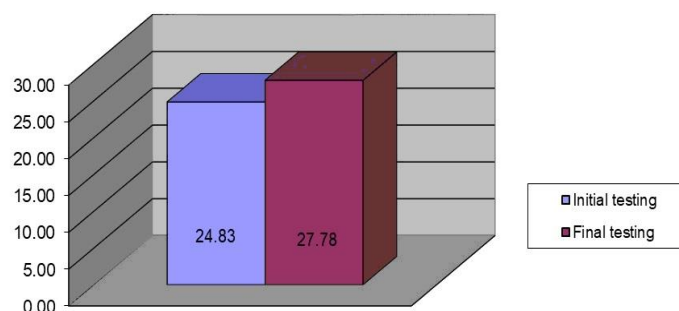


Fig. 5. Hitting the ball with the head from a static jumping position

## 5. Conclusions

The present study is part of a series of searches carried out by specialists in the field in order to increase the efficiency of the training session, the accuracy in passing the ball, its contribution to the training of future football player taking into consideration the requirements imposed by the modern football game.

Dash running being mainly determined by genetics a speed increase rate has been highlighted which needs to be researched further considering the biomechanical considerations, respectively the improvement of the running technique.

For the 2000 m endurance running, the obtained values present an increase by the reduction of the average time for the distance with approximately 7 s.

The speed strength (compression strength) of the inferior limbs highlight an optimum functional status of the muscular groups at this level.

The strength of the protractor muscles stagnates or regresses during this period which implies the large and varied use of strength training exercises destined for this group of muscles as well as those groups used while moving and performing technical movements (inferior limbs).

## 6. Recommendations

As it is all about a complex adaptation process of the body to permanent effort, passing to a new quality state of the capacity to withstand effort more importance needs to be given to effort dynamics during a lesson and respectively the recovery break.

## References

- Apolzan, D., 2000, *Fotbal 2010*, FRF, Bucharest.
- Ardelean, T., 2000, *Particularitățile dezvoltării calităților motrice în atletism*, Bucharest, IEFS Multiplication Centre.
- Bompa, T., 2002, *Periodizarea: Teoria și metodologia antrenamentului*, Bucharest, C.N.F.P.A. Ex Ponto.
- Bota C., Prodescu, B., 1997, *Fiziologia Educației Fizice și Sportului, Ergofiziologie*. Rm.Vâlcea, Ed. Antimivireanul.
- Cazorla G., 1990, Teste de teren pentru evaluarea capacității aerobe și a vitezei aerobe maxime. În *Evaluarea activității fizice și a sportului*. Actele colocviului internațional de la Guadelupa (ediția AREAPS).
- Cârstea, Gh., 2000, *Teoria și metoda educației fizice și sportului-pentru examenele de definitivat și gradul didactic II*, Bucharest, AN-DA Publishing
- Cernăianu, C., 2001– *Fotbal – Manualul antrenorului profesionist*, Bucharest, Ed.Rotech Pro
- Cojocaru, V., 2002, *Fotbal de la 6 la 18 ani-Metodica pregătirii*, Bucharest.
- Dragnea, A. și colab., 2000, *Teoria educației fizice și sportului*, București, Cartea școlii Publishing.
- Dragnea, A., Bota, A., 1999, *Teoria activităților motrice*, Bucharest, Didactică și pedagogică, R.A. Publishing.
- Epuran, M., 2005.- *Metodologia cercetării activităților corporale*, FEST Publishing., Bucharest
- Manno, R., 1992, *Les bases de l'entraînement sportif*, Paris, Edition Revue E.P.S.
- Motroc, I., Motroc, F., 1996, *Fotbalul la copii și juniori*, E.D.P., Bucharest.
- Rădulescu M., Cojocaru V., *Ghidul antrenorului de fotbal. Copii și juniori*. -Axis Mundi Publishing, Bucharest, 2003.
- Steleșcu, I., 2011, *Caracteristici psiho-sociale în jocul de fotbal*, Universitas Publishing, Petroșani.
- Steleșcu I., 2012; *Probleme ale capacității psihomotrice în fotbal*, Focus Publishing, Petroșani.
- Tudor, V., 1999, *Capacitățile condiționale, coordinative, și intermediare – componente ale capacității motrice*, Bucharest, RAI Publishing.
- Tudor, V., 2001, *Evaluarea în educația fizică școlară*, Bucharest, Printech Publishing.

## Physics Labs for Engineering Students: a Case Study Based on “Learning by Doing” Principles

Constantin Dan Buioca \*

*University of Petrosani, 20, University Street, 332006, Romania*

---

### Abstract

The work presents the main stages in preparing and performing a physics lab for engineering students (dependence on temperature of electrical resistance of a resistor), based on “learning by doing” principles: putting into evidence the theoretical and practical aspects of the studied phenomena; modeling and simulation using MathCAD software; conceiving experimental setup and measuring physical parameters; evaluation of theoretical and practical (real) experimental errors; estimation of practical applications. Steps to be followed and MathCAD programs presented allow an increase of measurements precision and fast acquiring of important practical skills.

*Keywords:* physics, lab, electric resistance, temperature, measuring errors, MathCAD, learning by doing

---

### 1. Introduction

The work presents a typical physics lab, based on modern “learning by doing” principles, because it allows to:

- Put into evidence the physical phenomenon and basic theoretical aspects, allowing the modeling and simulation of the studied phenomenon (dependence on temperature of the electrical resistance of a metal conductor);
- Conceive experimental set-up and measuring methods;
- Evaluate measuring errors (related to measuring apparatus);
- Process experimental data, using adequate software (MathCAD, in this case);
- Determine of governing theoretical law of studied phenomenon;
- Evaluate real measuring errors (including also random and caused by experimenter errors);
- Estimate possible applications of the studied phenomenon (using the conductor as temperature sensor, in this case).

### 2. Theoretical aspects

Metallic conductors have an electric resistance depending on temperature as:

$$R=R_0[1+\alpha(t-t_0)] \quad (1)$$

where  $R_0$  is the electrical resistance at initial temperature  $t_0$ , and  $\alpha$  is a thermal coefficient characterizing the resistor material.

Relation (1) describes a linear dependence of resistance with temperature:

$$R(t)=a+bt \quad (2)$$

which gives:

$$a=R_0(1-\alpha t_0) \quad (3)$$

---

\* Corresponding author. Tel.: +40-075-610-864.  
E-mail address: constantinbuioca@upet.ro.

$$b=R_0\alpha \quad (4)$$

Relation (1) allows experimental determination of the coefficient  $\alpha_e$  using measured values of resistance and temperature:

$$\alpha_e=(R-R_0)/R_0(t-t_0) \quad (5)$$

while relations (2)-(4) allow calculation using the found theoretical dependence  $R(t)$ :

$$\alpha_c=[R(t)-R(t_0)]/R(t_0)(t-t_0) \quad (6)$$

The quality of measurements is given by relative errors in determination of resistance and temperature:

$$\delta R=\Delta R/R \quad (7)$$

$$\delta t=\Delta t/t \quad (8)$$

where  $\Delta R$  and  $\Delta t$  are absolute errors in determination of resistance and temperature.

Finally, once the relation (2) determined, we can experimentally determine temperature if we measure resistance, as:

$$t=(R-a)/b \quad (9)$$

### 3. Experimental technique and data processing

Resistance and temperature were measured using high quality digital instruments, allowing absolute errors of  $\Delta R=0,1 \text{ } \Omega$  and  $\Delta t=0,1 \text{ } ^\circ\text{C}$ . Temperature sensor and resistor were introduced in an oven ensuring heating between 24 and 40  $^\circ\text{C}$ .

Measurements results were inserted in table 1.

Table 1.

Det. No.	t ( $^\circ\text{C}$ )	R ( $\Omega$ )	$\alpha$ ( $^\circ\text{C}^{-1}$ )	$\alpha_{\text{average}}$ ( $^\circ\text{C}^{-1}$ )	a ( $\Omega$ )	b ( $^\circ\text{C}^{-1}$ )	Obs.
1							
2							
...							

Measurements results were used in a MathCAD program presented below.

Results for temperature and resistance were inserted in vectors t and R, with element's index from 0 to 16 (figure 1):

The linear function  $R_{\text{teor}}(a,b,i)$  was defined, then a graphic was generated, for measured values ( $R_i, t_i$ ) and  $R_{\text{teor}}$ , for different values of constants a and b. After a few attempts, the result from figure 2, corresponding to  $a=33,95$  and  $b=0,19$  were obtained.

Relative errors are defined:

$$\delta R_{\text{teor}}(\Delta R, i) := \frac{\Delta R \cdot 100}{R_i}$$

$$\delta R_{\text{pract}}(i) := \frac{|R_{\text{teor}}(33.95, 0.19, i) - R_i| \cdot 100}{R_i}$$

This will allow their evaluation, as in figure 3.



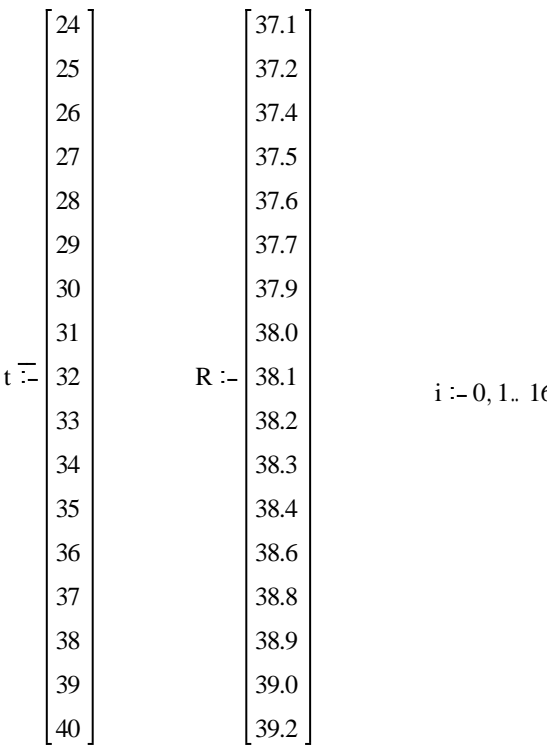


Fig. 1.

$R_{\text{teor}}(a, b, i) := a + b \cdot t_i$

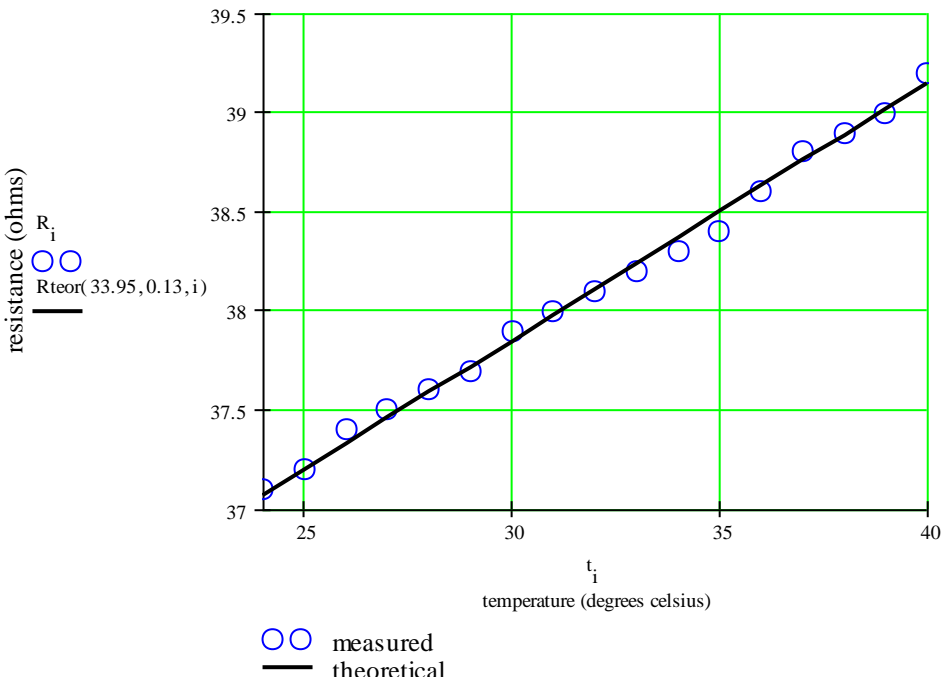


Fig. 2.

One can see very small errors, under 0.3%, determined by high quality instruments. But remarkable is that practical (final, after data processing) errors are even smaller, under 0.2%, because by data processing and establishing linear dependence, some measurement errors were removed. In other words, adequate processing of experimental data leads to an increasing of measurements accuracy.

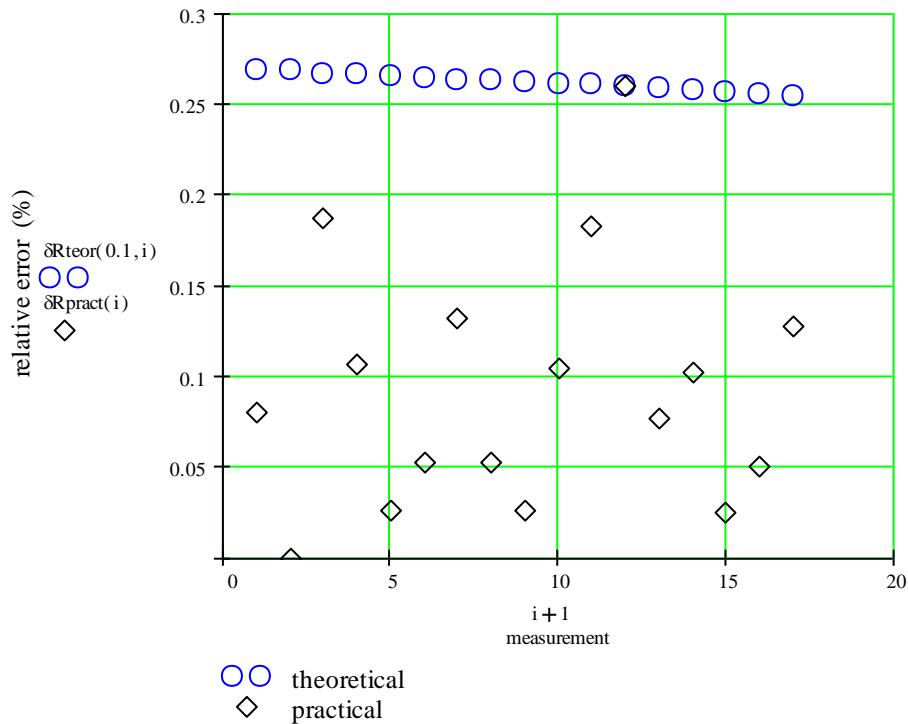


Fig. 3.

#### 4. Conclusions

Preparing and performing a physics lab for engineering students based on “learning by doing” principles allow the increase of efficiency of learning process. Students can learn faster and better how to put into evidence the theoretical and practical aspects of the studied phenomena; how to model and simulate a physical phenomena using a specialized software; how to conceive experimental setup and measure physical parameters; how to evaluate theoretical and practical (real) experimental errors; how to estimate practical applications. Steps to be followed and MathCAD programs presented allow an increase of measurements precision and fast acquiring of important practical skills.

#### References

- Buioca, C.D., Increasing Measurements Accuracy in Mechanical Experiments by Using MathCAD Data Interpolation, *Annals of University of Petrosani, Mechanical Engineering Series*, <http://www.upet.ro/annals/mechanical/pdf/2010/Annals-Mechanical-Engineering-2010-a6.pdf>. (2010)
- Buioca, C.D., PhysCAMP, a Computer Aided Modeling Platform for Physics, *Proceedings of International Conference ELSE2009, Bucharest, Romania, 2009* (<http://adlunap.ro/else2009/journal/papers/2009/965.1.Buioca.pdf>), Carol I National Defence Publishing House, 2009, ISBN 987-973-663-717-9, pp. 289 – 296 (2009)
- Reese W. , The Learning-by-Doing Principle, *Hayne West Virginia University*, <http://psycnet.apa.org/fulltext/2014-55719-001.pdf> (2014)

## Optical study of Saharan dust transported in Jiu Valley in 2018

Constantin Dan Buioca \*

*University of Petrosani, 20, University Street, 332006, Romania*

---

### Abstract

Dust particles from Sahara, transported by wind and rain in Jib Valley, in April 2018, as well as typical dust found before and after, were studied using an optical Zeiss microscope. The obtained images were processed using Windows Paint and MathCAD software. Results were compared with theoretical ones, obtained by MathCAD simulation of dust transport by wind in Sahara Desert. The study put into evidence that Saharan dust particles are mainly reddish quartz ones, having dimensions between 50 and 100 microns, not really dangerous, but causing some discomfort.

*Keywords:* optical microscopy, MathCAd, simulation, wind transport, saharan dust, Jiu Valley,

---

### 1. Introduction

For the beginning, why this research subject?

A simple answer: the orange snow from fall March and reddish dust from beginning April 2018, all Saharan provenience, were media news intriguing – but without any scientific details. Searching that kind of details, one can see that there are none, that's why I've took dust samples and studied them using optical microscopy.

City dust is an important atmospheric pollutant, created by human activities but also by natural phenomena – like storms or volcanic eruptions. Knowing dust's physical and chemical characteristics allows the evaluation of its impact on environment and especially on humans, as well as establishing methods to reduce impact.

Clinical studies show that most frequently found dust particles, having dimensions between 1 and 100 microns, determines only discomfort during inhalation. Most dangerous particles are those with dimensions between 0.1 and 1 microns, which are breathable and are blocked in loans alveoli. Particles under 0.1 micron are breathable but, caused by Brownian motion, behave like gases and are eliminated from loans during exhalation.

### 2. Theoretical aspects

A first aspect is related to the size of the particles that we expect to find in Saharan dust transported on thousands kilometers after a desert storm.

In order to evaluate the particle's (considered spherical) radius, we must compare their weight against the drag (by wind) force:

$$G=4\pi r^3\rho g/3 \quad (1)$$

$$F_d=6\pi\eta r v \quad (2)$$

where  $g=9,8 \text{ m/s}^2$  is free fall acceleration,  $r$  is the particle's radius,  $v$  is wind velocity,  $\rho$  is the particle's density (for quartz/sand,  $\rho=2500 \text{ kg/m}^3$ ), and  $\eta$  is the air's dynamic viscosity coefficient ( $\eta=1,81\cdot 10^{-5} \text{ kg/m.s}$ ).

---

\* Corresponding author. Tel.: +40-075-610-864.  
E-mail address: constantinbuioca@upet.ro.

Equalizing the two forces, one get the minimum speed of wind lifting the particle:

$$v = 2r^2 \rho g / 9\eta \quad (3)$$

Evaluation of this velocity with a MathCAD program gives the result seen in fig. 1.

$$r := 10^{-6}, 2 \cdot 10^{-6} \dots 3 \cdot 10^{-4}$$

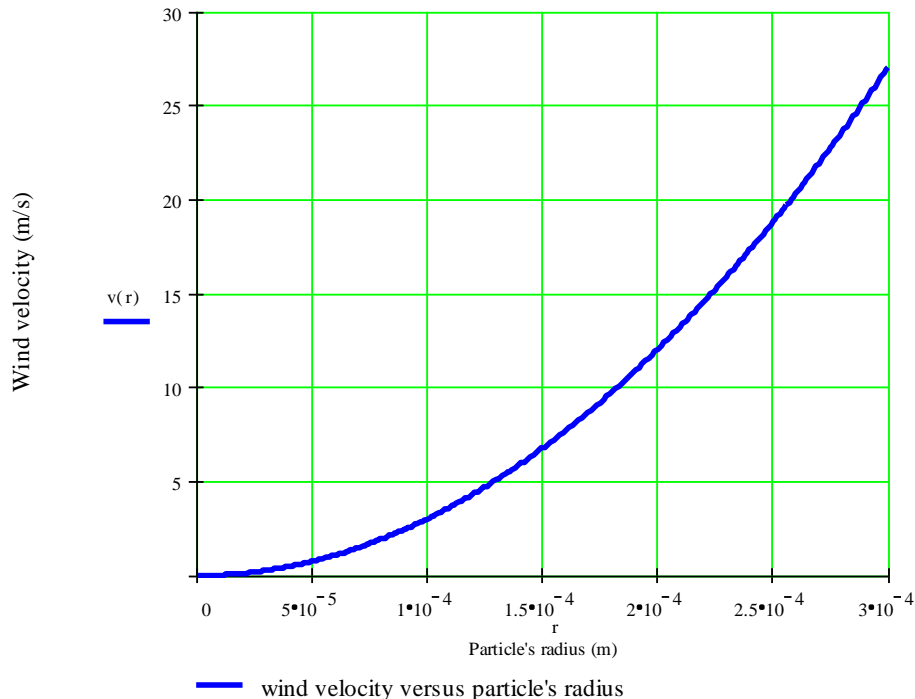


Fig. 1.

As one can see, a weak wind of a few m/s, lifts particles of a few microns, while strong wind (storm) of a few tens of m/s lifts particles having dimensions of tens of microns or bigger. We will expect then that Saharan dust particles transported by storms will have dimensions of tens of microns or bigger, depending on the intensity of the storm who lifted the particles.

The second aspect is related on the theoretical minimum dimension of the detected particles. It depends on the microscope's power and digital picture's quality. A correspondence pixel-length can be established using a scale, as shown in figure 2. Reading the image's characteristics reveals that it has 4608 pixels corresponding to 2.5 mm of scale, therefore 1 pixel=0.5  $\mu$ m. Theoretically, we can put into evidence particles having 1  $\mu$ m diameter.

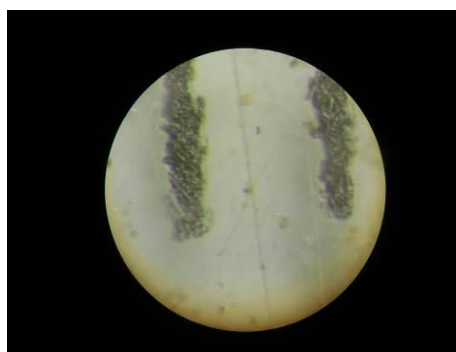


Fig. 2.

### 3. Experimental results

Samples of Saharan particles were obtained from rain drops, by water evaporation. For comparison, samples of usual city particles were obtained, one week after the studied phenomenon.

Pictures were obtained using a Zeiss optical microscope, with a magnification of  $4 \times 200$ , captured with a camera Nikon Koolpix L610 at quality  $4608 \times 3456$  pixels. The obtained pictures were analyzed using Windows Paint – allowing the display in pixels of picture's or particle's dimensions.

Figure 3 shows typical pictures of observed particles, including Saharan ones. One can see 4 different types of particles.

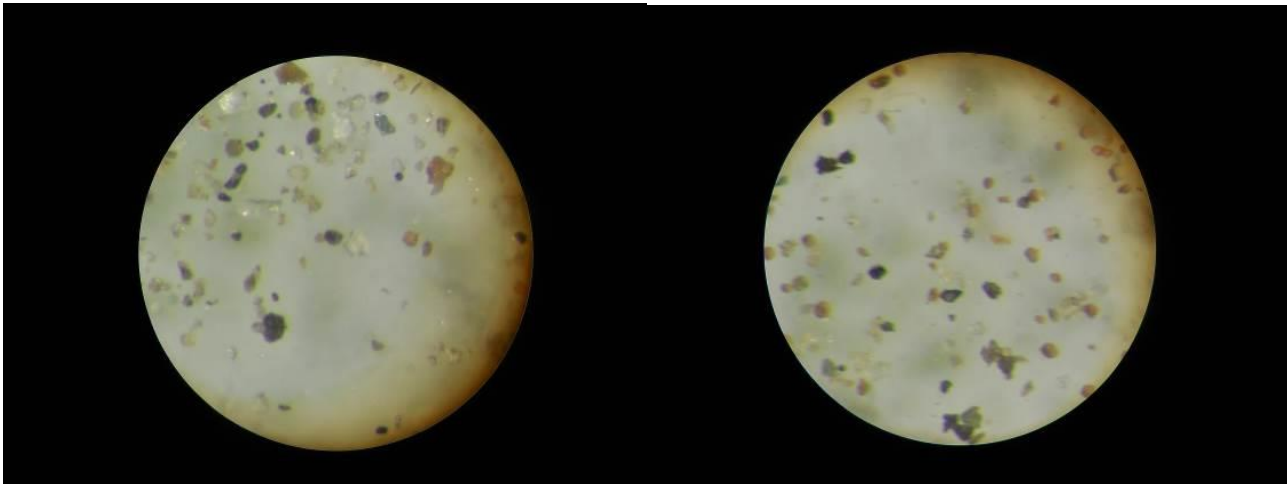


Fig. 3.

The first type is the reddish ones, characteristic to Sahara desert, having dimensions between 50 and 100 microns. These are particles of quartz with iron impurities, similar to those observed in Sahara desert.

The second type is the shining-white ones, having dimensions between 50 and 100 microns, less frequent than the first ones. These are particles of (almost pure) quartz, of local provenience, lifted by local wind or vehicles.

The third type is black particles, relatively frequent, having dimensions between 20 and 70 microns. These are polluting particles from Diesel engines.

The last type is the very small shining-white particles, having dimensions of a few microns. These appear in pictures with in-door dust, therefore are not Saharan ones.

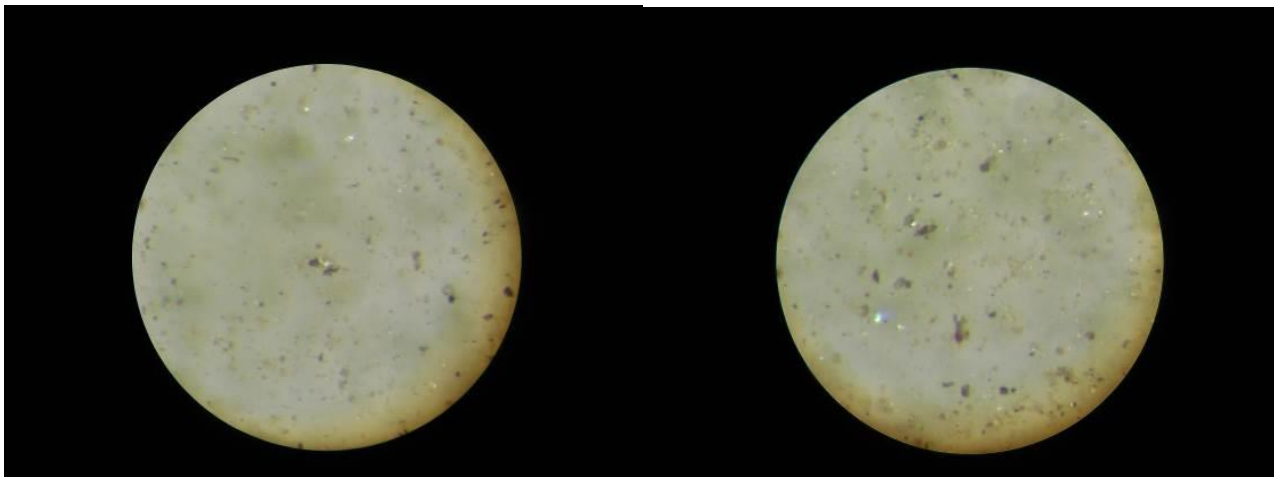


Fig. 4.

For comparison, figure 4 shows pictures obtained one week after the Saharan event. One can see that most particles are small, rarely reaching 50 microns, rarely reddish.

#### **4. The MathCAD program**

The MathCAD program for simulation of particles drag by wind is presented in figure 5.

The program logic is obvious. Values are given for involved parameters, and then the formula of wind velocity is defined. The graphic of wind velocity as a function of particles radius is generated. For details, see author's book, specially written for beginner MathCAD users.

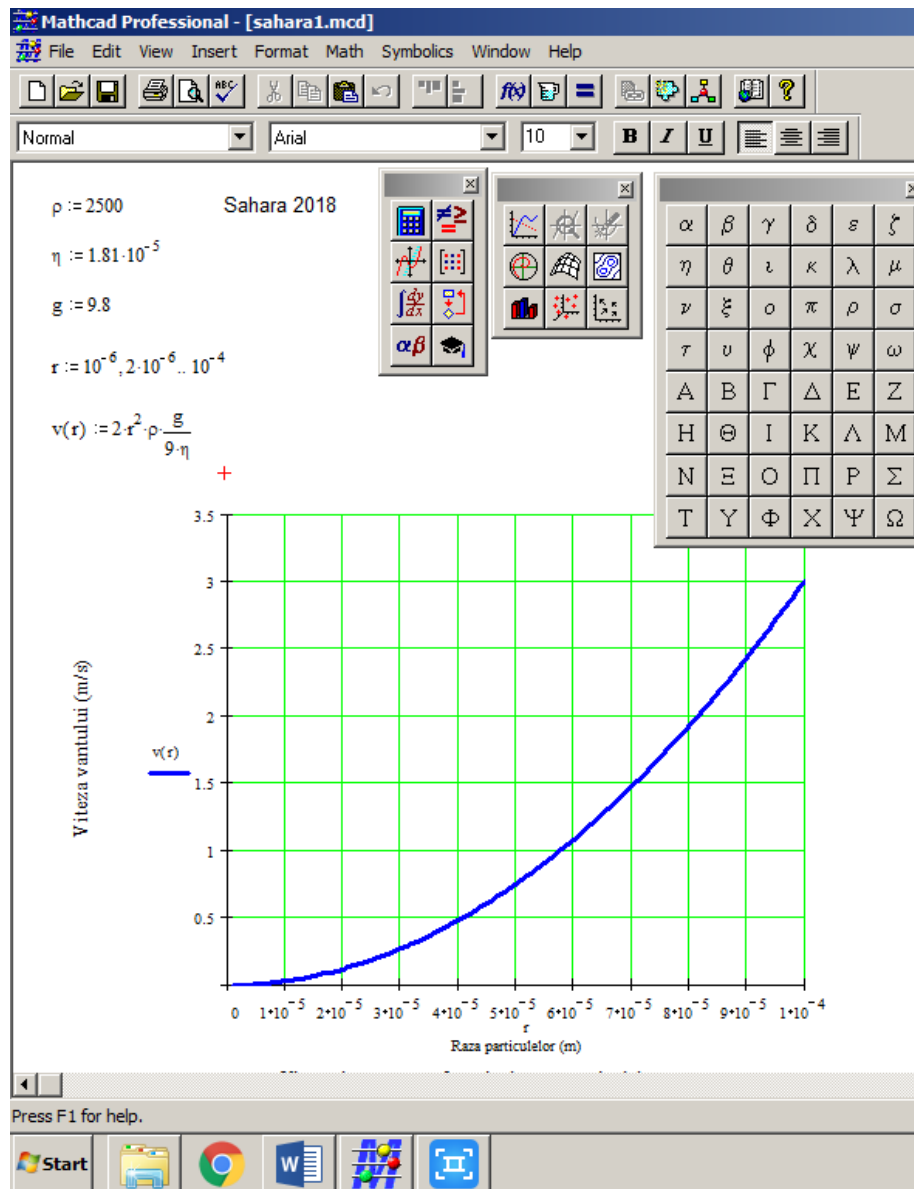


Fig. 5.

## 5. Conclusions

Microscopic analysis of dust transported in Jiu Valley from Sahara desert put into evidence the presence of typical reddish quartz Saharan particles, having dimensions between 50 and 100 microns. These are not significantly affecting the quality of air, on both atmospheric and ground level, because after water evaporation they are staying on ground level, in small amounts, and (being so big) are not lifted in air by usual wind. Even if lifted by strong wind, they are not a real danger for humans, causing eventually a small discomfort.

## References

- Buioca, C.D., Microscopic Analysis of out-door Dust Sedimented in the „Iceland Volcano Week”, Proceedings of *Int. Conf. CONFERENG 2010*, Univ. “Constantin Brancusi” Tg. Jiu, Romania, *Annals of the “Constantin Brancusi” University of Tg. Jiu, Eng. Series*, No.2, pp. 398-405 (2010)
- Buioca, C.D., *Modelling and simulation of physical phenomena with MathCAD, Vol. I, Mechanical phenomena*, Universitas Publ. House, Petrosani, Romania, (2010)
- <http://www.claygroundcollective.org/pottery-from-rain-and-saharan-dust-an-article-from-javier-cuadros-clay-mineralogy-researcher/>

# Sustainable Development - Never Fulfilled Dream

Janusz Grabara<sup>a</sup> \*

*<sup>a</sup>The Management Faculty, Czestochowa Univeristy of Technology*

---

## Abstract:

The sustainable development can be introduced in different ways. It is necessary to consider whether for sustainable development, it is possibility to create universal model. The model has to fulfil certain requirements and at the same time as simple as possible to implement elements of sustainable development. It is necessary to remember, while creating this model, that some particular streams of elements, which allows to form sustainable development influence one another. The paper, it is the introduction concept of such a model, which takes into consideration streams of sustainable development management. It is necessary to present impossibility of full realization of sustainable development. Because, there are a few important factors. At first it is electricity over 65% is produced from coal, natural gas and oil. The new regulations and trends give us information about limitation of classic fuel engine cars sell since 2015 in Netherlands and Norway. It will prohibited selling of new cars excluding electrical cars. The same situation will obligate citizens of UK in 2025. Short analysis gives us information that it will be not enough energy for supply electric cars and the rest electricity consumers. Considering those situations, the Author discuss real possibility of sustainable development introduction as well as proposes new model of sustainable development evaluation.

*Keywords sustainable development system, matrix, set*

---

## 1. Introduction

The space that covers the whole of sustainability is enormous. In a short article it is difficult to list all aspects, factors and conditions, which is why the article signals some elements of sustainable development. Some big business acts contradict sustainable development policies through semi-illegal or illegal activities to reduce product use time only to increase the sales of newly produced goods. This paper presents the definitions of sustainable development as well as the groups of issues related to these definitions including the comments. The aim of this article is to show that under current conditions, the global introduction of sustainable development is impracticable and the prospects are very distant

## 2. Sustainable development critical literature review

Nowadays, environment and ecology preservation become more important. Better political, social and economic management involves respecting and protecting surrounding wildlife. Humankind became more aware of the environmental issues and now it values acts that have positive impact on nature and criticizes those who contribute to environmental depletion (Grabara 2017; Adamisin et al., 2018). This philosophy is not something new because almost 50 years ago the destructive effect of industrialization on environment was clearly emphasized. On June 16, 1972 the definition of sustainable development came into being and its political, economic and social aspects were discussed in the Declaration of the United Nations Conference on the Human Environment. After that, sustainable development was defined as follows: "the right to meet the development aspirations of the present generation, without limiting the rights of future generations". Hence, present economic expansion cannot reduce future generation's chance for the same economic development. Using natural resources should be done reasonably and responsibly in order to avoid situation where future generation will have not enough reserves to sustain themselves. There are two ways of looking at the

---

\* Corresponding author. Tel.: +48 604 16 39 22; fax: +48 34 325 0244.  
E-mail address: janusz@grabara.eu.

definition of sustainable development. The first is that this process refers to one country or city. The wider context indicates that it is a global phenomenon including the future of next generation. It is said that sustainable development is "a sequence of changes in which, the use of resources, the structure of investments, orientation of technological progress and institutional structures can be carried out in such a way, that there will be no contradiction between the future and present needs". J. Adamczyk and T. Nitkiewicz (2007) suggested that when it comes to sustainability, well-balanced development is a key and "...consists in establishing the connection between the economic and social development by assuring an access to the renewable and non-renewable resources together with improving quality of life in a natural and clean environment. Economic development ought to assure a more effective utilization of natural resources and other resources of nature, rationalization of the input of energy and work, as well as the development of pro-ecological technologies and the protection of environmental and cultural heritage. Thus, the continuous and sustainable development is a humanitarian concept of global development, whose basic feature is the improvement of the quality of life and welfare of mankind under the conditions of a limited availability of natural resources, taking into account the far-reaching consequences of industrial development. This concept assumes a common responsibility and solidarity of the present and future generations." Another definition of sustainable development was constructed by D. Loorbach (2010) who stated that "Sustainable development is a process of change (development), which implements the feature of balance assessed positively in terms of at least anthropocentric system of values or less, less precisely though – it is development with the sustainability attribute". During the United Nations Conference "Environment and Development" (Rio de Janeiro, 3rd-14th of June 1992) twenty-seven principles of sustainable development were constituted in order to confirm the declaration of the United Nations Conference on the Human Environment. Until today, these principles are the most complex and most relevant definition of sustainable development. They contributed towards establishing new and equal partnerships between countries and between nations and fundamental social groups. Moreover, it facilitated the process of creating "international agreements, favorable for everybody and protect the integrity of the global environment and development system, recognizing the indivisible and interdependent nature of the Earth's affiliate, our home". Nowadays, there are two concepts of development. Firstly, we distinguish the development of conventional thinking which assumptions relate to the present generation and achieving material stability. In this model high rate of economic growth is essential for social and economic improvements. The effect of industrial development on ecosystem is not taken into account. On the other hand, there is a concept of sustainable development where future ecological and social situation are included in the process of managing economic expansion. The main purpose of sustainable development is to increase, not only the level, but also the quality of life. One of the most important aspects of sustainable development is that human needs must not breach the stability of ecosystems (Grabara et al., 2016; Dobrovolskienė, et al., 2017; Askadilla, et al., 2017). Furthermore, human development respects and protects natural environment at present and has positive impact on the future. Sustainability means using the resources of natural environment in a reasonable way – the level of utilization is high and the level of waste is minimal. Eco-development is sometimes used as a synonym for sustainable development. When discussing the idea of sustainable development, one of the definitions states that it is a balance between economy, environmental issues and culture. In this connection, humankind should not disrupt surrounding wildlife while enhancing economic growth. Sustainability is also achieved when future generation can still benefit from the same environment. There are several definitions of sustainable development and these are some of the most popular. First one states that "sustainability is conducting any business in harmony with nature, so not to cause irreversible changes in the nature or the management of environmentally acceptable, socially desirable and economically viable". The next one defines sustainable development as "socio-economic development harmonized with the natural environment, both local and wider - including the various ecosystems and resources, and the structure of soil, water, geological and atmospheric and generally understood the beauty of the landscape in order to preserve their values in the longest possible time intervals". According to another definition "sustainability is a comprehensive harmonization of economic activities with the possibilities of the natural environment". The concept of sustainability may be a result of increasing awareness of environmental damage done by rapid industrialization, human development and culture. It is a global issue referring to the knowledge that some of the resources are not renewable and may be depleted. This can be done by inappropriate use of these reserves at present which may cause unstable and uncertain situation for future generation.

### **3. Sustainable development today**

From a practical point of view, the idea of sustainable development is the introduction of so-called. "integrated governance", which would integrate environmental governance, socio-economic, spatial and institutional and political order. It follows, that sustainable development can be achieved only in the case of conducting environmental, socio-economic and spatial policy (Kot, 2018; Mashokhida, et al., 2018; Rajnoha and Lesníková, 2016; Ilysheva, et al., 2017; Streimikiene, et al., 2016).

In pursuit of sustainable development, development of environmental awareness is extremely important. "The awareness term determined the relationship of man to nature, the team of the information and beliefs about it, and the system of values, which is directed against him on in his ways".

"Environmental issues are closely linked to social, economic, and cultural factors and cannot be solved only through technological means. The attitude of people to the natural environment, depends on their awareness, that is, their



knowledge and beliefs about the environment, and the values which guided them in conduct towards the environment. To make people aware of environmental degradation and the consequences flowing from the last few decades, has resulted in a change in environmental awareness and, consequently, of the Initiative practices".

### **Difficult to carry out the task of sustainable development**

The Sustainable Development Conference (Rio + 20), held in Rio de Janeiro in June 2012, outlined four key elements needed to realize global sustainability. These are: planet Earth, prosperity, world peace and partnership.

The composition of these elements seems impossible.

Our planet, we want to protect the Earth from deteriorating environment through sustainable consumption and production, sustainable management of natural resources and taking urgent action against climate change, supporting the needs of present and future generations.

Prosperity, we want to ensure that all people have a dignified and satisfying life and that economic, social and technological development is in harmony with nature.

Peace in the world, we build peaceful and inclusive societies, free of fear and violence. There is no sustainable development without peace, and there is no peace without sustainable development.

We will mobilize the resources needed to implement this agenda by revitalizing the Global Partnership for Sustainable Development in the spirit of enhanced global solidarity, focusing in particular on the needs of the poorest and most vulnerable groups, and in the cooperation of all states, parties and people around the world. Protect the planet from deteriorating environmental conditions through sustainable consumption and production, sustainable management of natural resources and urgent action against climate change, supporting the needs of present and future generations.

This is a wish for no chance for realization. There are many elements that have a significant impact on the realization of this postulate. The most known aspect of the negative impact humans have on our planet is climate warming, which is a fact and we all feel its effects in the form of more frequent and stronger hurricanes, typhoons and floods and tsunamis.

The next element is deforestation, where, despite the loss of habitat, especially in Africa and South America, there are about 4 million hectares a year. This progress contributes to the increase of desert areas. About 20 million hectares of land surface annually.

Fuel and energy are also a frighteningly important factor. We consider this as coal, natural gas and oil. There are two reasons for this concern. Firstly, the use of these fuels contributes to the greenhouse effect as well as to the formation of smog (Tvaronaviciene, 2018; Popp et al., 2018a, Grabara and Kot, 2017) and secondly, the reserves of these minerals, with only 34 billion barrels of oil extracted annually, are significantly reduced with coal and gas. Energy consumption is still increasing, with an approximate 570 EJ consumed at the primary energy level in 2014. Of this total 78.3% was provided by fossil fuels, 2.5% from nuclear, 8-9 by biomass mainly from wood combustion, 3.9% from hydro, and 6.4% from other renewable energy sources (Oláh et al., 2017; Tvaronaviciene, et al. 2018; Mikita et al., 2017). Transport biofuels are currently the fastest growing bioenergy sectors even they represent around 3-4% of total road transport fuel and only 6% of total bioenergy consumption today. Low oil prices and poor margins continue to challenge biofuel producers in Europe (Popp et al., 2018a).

Similarly, in the area of electricity production where only about 5 percent of energy is produced using new technologies in renewable sources, about 16% in hydroelectric plants, and 12% generate nuclear power plants. The distribution of these power plants is disproportionate, for example, nuclear power supplies more than 80 percent of electricity demand in France, and in Germany the share of this energy system is decreasing, which is linked to successive shutdowns of nuclear power plants. However, on a global scale, more than 40% of electricity produced is coal-based, leading in China and the United States.

The third element is extinction, a very tragic phenomenon, as it causes irreversible loss of many species of flora and fauna as the so-called "butterfly effect" causes irreversible changes in the ecosystem of the Earth.

Elements are definitely more that we could attribute to the concept of Earth from a sustainable development perspective.

The next major element outlined by the Sustainable Development Conference (Rio + 20) is Prosperity.

Prosperity is a difficult concept to define, prosperity is something that should give all people a dignified and satisfying life and make economic, social and technological development in harmony with nature. The concept of prosperity is probably the fastest evolving concept of our times, and one could even argue that it evolves faster than the ICT industry.

In terms of social (i.e. non-personal) this awareness of prosperity arises from the conditions of "being". Simplifying things strongly: As people bring down to the level of satisfying the basic needs (even according to the Maslow classification), "we will shape their "consciousness" very shallow and superficial, but very dangerous - they will have nothing (or almost nothing) to lose and formed a class of opponents All people living so long in the margins that it will be for them a field of their "normal" action". Therefore, achieving global prosperity seems very remote in time.

Peace in the world, we build peaceful and inclusive societies, free of fear and violence. There is no sustainable development without peace, and there is no peace without sustainable development.

According to a recently published work, by July 2011 nearly 500,000 people died in the Iraq war. people. Another work (Iraq Body Count), which is based on mass media reports, shows that by December 2012, 110,000 died.

Estimates include: The share of civilian war victims increased from 5 to 90 percent in the last hundred years. So it does not seem possible to extinguish all armed conflicts in the near, future or even very distant future.

The last of these is partnership (Popp et al., 2018b). Partnership as well as global peace are elements of utopian thinking. The brutal reality shows that they win particular interests, nationalisms, and similar macro-level, micro and nano factors on the good of the whole of humanity and the implementation of sustainable development. It should also be mentioned that the debt of the majority of states is so great, reaching up to about 90% of GDP, which makes it impossible to step up efforts to remove obstacles to sustainable development.

Threats in sustainable development currently affect not only our planet, but also its surroundings, which has been postponed by NASA.

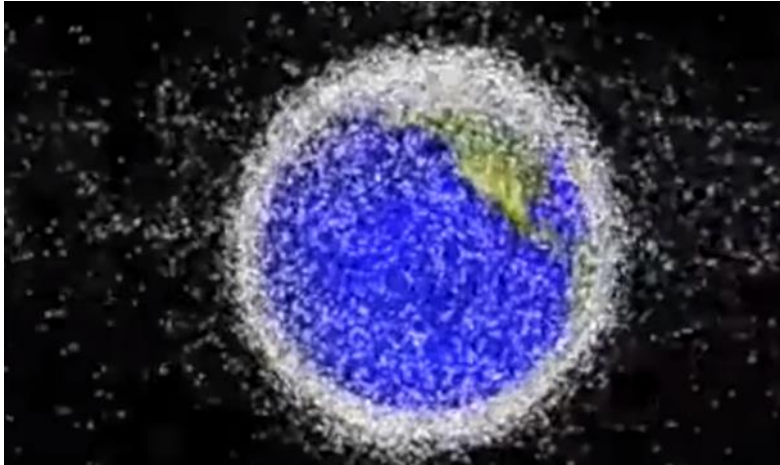


Fig. 1 White Dots mean garbage left after the implementation of space programs orbiting the Earth

#### 4. Model of sustainable development progress

Sustainable development process can be introduced in different ways. One of such ways in the tables used is structural analysis, which take into consideration sustainability and economic policy divisions or determine directions of Sustainable development progress in the world with use of simulation methods. All methods that progressing sustainable development can be introduced as right structural models.

It is necessary to think whether for sustainable development progress there is possibility to create universal structure, which allows building sustainable development structure model. The model has to fulfil certain requirement at the same time as simple as possible to implement.

In this paper it is a trial of introducing of such model, which take into consideration sustainable elements and their interaction. This model consists of matrix mutual connections sustainable elements and economic policy decisions.

Let us include factors mentioned by Sustainable Development Conference (Rio + 20):

Prosperity and Peace also the Negative impact humans, Extinction and Debt of the majority of states. We can try to determine the weight of these four factors, but this seems insufficient, as according to the author, one more factor should be included. We can call it random factor, as it depends on the countries' and regions' ability to eliminate the outcomes of natural disasters, like earthquakes, floods, wildfires, volcanic eruptions and industrial disasters.

These factors are strictly related to each other.

Using the matrix projection of elements' configuration and streams, the relation  $*_{ik}$ , created by particular factors  $D_i$

Using here and aforementioned characteristics of matrix record allows read for each factor all links ingoing to its and outgoing from its.

And so:

relation ensuring from Peace and Prosperity P (D1)

$$*_{11} = f_1(d_{12}, d_{13}, d_{14}, d_{15}, d_{21}, d_{31}, d_{41}, d_{51}, z_{11}, z_{21}, z_{31}, z_{41}, z_{51}, z_{61})$$

relation ensuring from Negative Impact Humans N (D2)

$$*_{22} = f_2(d_{21}, d_{23}, d_{24}, d_{25}, d_{12}, d_{32}, d_{42}, d_{52}, z_{12}, z_{22}, z_{32}, z_{42}, z_{52}, z_{62})$$

relation ensuring from Extension E (D3)

$$*_{33} = f_3(d_{31}, d_{32}, d_{34}, d_{35}, d_{13}, d_{23}, d_{43}, d_{53}, z_{13}, z_{23}, z_{33}, z_{43}, z_{53}, z_{63})$$

relation ensuring from Debt of the majority of states D (D4)

$$*_{44} = f_4(d_{41}, d_{42}, d_{43}, d_{45}, d_{14}, d_{24}, d_{34}, d_{54}, z_{14}, z_{24}, z_{34}, z_{44}, z_{54}, z_{64})$$

relation ensuring from Random factor R (D5)

$$*_{55} = f_5(d_{51}, d_{52}, d_{53}, d_{54}, d_{15}, d_{25}, d_{35}, d_{45}, z_{15}, z_{25}, z_{35}, z_{45}, z_{55}, z_{65})$$

Matrix record of investigated structure will provide identification of those relation as a function of ingoing factors to framework of system. It will be relations effecting on Sustainable Development Progress particular factors flowing from blocks detailed determining relation.

Table 1. Matrix projection of elements' configuration as well as procedural and subjected streams of sustainable development progress.

	W <sub>1</sub>	W <sub>2</sub>	W <sub>3</sub>	W <sub>4</sub>	W <sub>5</sub>	W <sub>6</sub>	D <sub>1</sub>	D <sub>2</sub>	D <sub>3</sub>	D <sub>4</sub>	D <sub>5</sub>
D <sub>1</sub>	φ <sub>11</sub>	φ <sub>12</sub>	φ <sub>13</sub>	φ <sub>14</sub>	φ <sub>15</sub>	φ <sub>16</sub>	0	d <sub>12</sub>	d <sub>13</sub>	D <sub>14</sub>	d <sub>15</sub>
D <sub>2</sub>	φ <sub>21</sub>	φ <sub>22</sub>	φ <sub>23</sub>	φ <sub>24</sub>	φ <sub>25</sub>	φ <sub>26</sub>	d <sub>21</sub>	0	d <sub>23</sub>	D <sub>24</sub>	d <sub>25</sub>
D <sub>3</sub>	φ <sub>31</sub>	φ <sub>32</sub>	φ <sub>33</sub>	φ <sub>34</sub>	φ <sub>35</sub>	φ <sub>36</sub>	d <sub>31</sub>	d <sub>32</sub>	0	D <sub>34</sub>	d <sub>35</sub>
D <sub>4</sub>	φ <sub>41</sub>	φ <sub>42</sub>	φ <sub>43</sub>	φ <sub>44</sub>	φ <sub>45</sub>	φ <sub>46</sub>	d <sub>41</sub>	d <sub>42</sub>	d <sub>43</sub>	0	d <sub>45</sub>
D <sub>5</sub>	φ <sub>51</sub>	φ <sub>52</sub>	φ <sub>53</sub>	φ <sub>54</sub>	φ <sub>55</sub>	φ <sub>56</sub>	d <sub>51</sub>	d <sub>52</sub>	d <sub>53</sub>	D <sub>54</sub>	0
W <sub>1</sub>	s <sub>11</sub>	s <sub>12</sub>	s <sub>13</sub>	s <sub>14</sub>	s <sub>15</sub>	s <sub>16</sub>	z <sub>11</sub>	z <sub>12</sub>	z <sub>13</sub>	Z <sub>14</sub>	z <sub>15</sub>
W <sub>2</sub>	s <sub>21</sub>	s <sub>22</sub>	s <sub>23</sub>	s <sub>24</sub>	s <sub>25</sub>	s <sub>26</sub>	z <sub>21</sub>	z <sub>22</sub>	z <sub>23</sub>	Z <sub>24</sub>	z <sub>25</sub>
W <sub>3</sub>	s <sub>31</sub>	s <sub>32</sub>	s <sub>33</sub>	s <sub>34</sub>	s <sub>35</sub>	s <sub>36</sub>	z <sub>31</sub>	z <sub>32</sub>	z <sub>33</sub>	Z <sub>34</sub>	z <sub>35</sub>
W <sub>4</sub>	s <sub>41</sub>	s <sub>42</sub>	s <sub>43</sub>	s <sub>44</sub>	s <sub>45</sub>	s <sub>46</sub>	z <sub>41</sub>	z <sub>42</sub>	z <sub>43</sub>	Z <sub>44</sub>	z <sub>45</sub>
W <sub>5</sub>	s <sub>51</sub>	s <sub>52</sub>	s <sub>53</sub>	s <sub>54</sub>	s <sub>55</sub>	s <sub>56</sub>	z <sub>51</sub>	z <sub>52</sub>	z <sub>53</sub>	Z <sub>54</sub>	z <sub>55</sub>
W <sub>6</sub>	s <sub>61</sub>	s <sub>62</sub>	s <sub>63</sub>	s <sub>64</sub>	s <sub>65</sub>	s <sub>66</sub>	z <sub>61</sub>	z <sub>62</sub>	z <sub>63</sub>	Z <sub>64</sub>	z <sub>65</sub>

Assuming the result of these computations must fit in between 0 and 1, where zero means lack of any progress in sustainable development and 1 means proper progress, it could be possible to determine how advanced are actions in field of the sustainable development.

## Conclusion

Based on the available data, it can be concluded there is no evidence for effective implementation of sustainable development rules at the moment. Furthermore, there is little chance they will occur in the future. Because of this article's space limits, detailed relations and computations are not included.

Considering study limitations, it should be stated that the model is in initial stage of elaboration and it was calculated based on pilot data collection. The model will be developed both in theoretical sphere as well as using large data sets. Those action would allow for more independent and reliable sustainable development evaluation.

## References

- Adamczyk J., Nitkiewicz T., Programowanie zrównoważonego rozwoju przedsiębiorstw. PWE, Warszawa, (2007)
- Adamisin, P., Kotulic, R., Mura, L., Kravcakova Vozarova, I., Vavrek, R. Managerial approaches of environmental projects: An empirical study. *Polish Journal of Management Studies*, 17 (1), pp. 27-38. (2018)
- Askadilla, W.L., Krisjanti, M.N., Understanding indonesian green consumer behavior on cosmetic products: Theory of planned behavior model, *Polish Journal of Management Studies*, 15(2), 7-15. (2017)
- Dobrovoltskienė, N., Tvaronavičienė, M., Tamošiūnienė, R., Tackling projects on sustainability: a Lithuanian case study, *Entrepreneurship and Sustainability Issues*, 4(4), 477-488, (2017)
- Grabara, J., Kot, S. Smog - Are power plants guilty ? Proceedings of the 9th International Scientific Symposium on Electrical Power Engineering, Elektroenergetika 2017, pp. 26-29. (2017)
- Grabara, J.K., The another point of view on sustainable management, *Quality - Access to Success*, 18, 344-349 (2017)

- Grabara, J., Vlăduțescu, Ș., Kot, S., Philosophical background of reverse logistics, *Analele Universitatii din Craiova, Seria Filozofie*, 38(2), pp. 158-167, (2016)
- Ilysheva, N., Baldesku, E., & Zakirov, U. Detection of the Interdependence of Economic Development and Environmental Performance at the Industry Level. *Montenegrin Journal of Economics*, 13(4), pp. 19-29, (2017)
- Kot, S., Sustainable Supply Chain Management in Small and Medium Enterprises. *Sustainability* Vol. 10, No. 1143, (2018)
- Loorbach, D. Transition management for sustainable development: a prescriptive, complexity- based governance framework. *Governance*, 23(1), pp. 161-183. (2010).
- Mashokhida, A., Khabibovich, A. A., Pálka, P., & Shakhlo, R. The Competitiveness and Sustainable Economic Development of Tajikistan Regions. *Journal of Competitiveness*. Vol. 10, Issue 1, pp.73-88, (2018).
- Mikita, M., Kolcun, M., Špes, M., Vojtek, M., Ivančák, M., Impact of electrical power load time management at sizing and cost of hybrid renewable power system *Polish Journal of Management Studies*, 15(1), 154- 162. (2017)
- Moraru, R.I., Băbuț, G.B., Cioca, L.I., *Knowledge management applications in occupational risk assessment processes*, Proceedings of the 17th International Conference - The Knowledge-Based Organization: Management and Military Sciences, pp. 735-740, Sibiu, Romania (2011).
- Oláh, J., Lengyel, P., Balogh, P., Harangi-Rákos, M., Popp, P. The Role of Biofuels in Food Commodity Prices Volatility and Land Use. *Journal of Competitiveness*, Vol. 9, No. 4., pp. 81-89. (2017)
- Popp, J., Kot, S., Lakner, Z., Oláh, J. Biofuel use: Peculiarities and implications. *Journal of Security and Sustainability Issues*, 7 (3), pp. 477-493, (2018a)
- Popp, J., Kiss, A., Oláh, J., Máté, D., Bai, A., Lakner, Z. Network Analysis for the Improvement of Food Safety in the International Honey Trade, *Amfiteatru Economic*, Vol. 20. No. 47., pp. 84-98. (2018b)
- Rajnoha R., Lesníková P., Strategic Performance Management System and Corporate Sustainability Concept - Specific Parametres in Slovak Enterprises, *Journal of Competitiveness*, 8(3), 107-124, (2016)
- Streimikiene, D., Navikaite, A., & Varanavicius, V. Company's Value Creation Via Customer Satisfaction and Environmental Sustainability Influence. *Montenegrin Journal of Economics*, 12(4), 19-28. (2016).
- Tvaronaviciene, M. Towards sustainable and secure development: Energy efficiency peculiarities in transport sector, *Journal of Security and Sustainability Issues*, Vol. 7, Issue 4, pp. 719-725 (2018).
- Tvaronavičienė, M., Prakapienė, D., Garškaitė-Milvydienė, K., Prakapas, R., Nawrot, Ł. Energy efficiency in the long run in the selected European countries, *Economics and Sociology*, 11 (1), pp. 245-254. (2018)

## Role of ergonomics in sustainable development

Maria Elena Boatca<sup>a\*</sup>, Anca Draghici<sup>a</sup>

<sup>a</sup>Politehnica University of Timișoara, 14 Remus street, Timisoara 300191, Romania

---

### Abstract

In the current sociopolitical context, sustainable development is a subject of major importance considering the concerned statistics and disastrous impact of the resource-intensive economic model. Considering more countries' concern for environmental protection and the urgent need of a more sustainable lifestyle and economic practice, ergonomics could be the solution for certain problems. As for the International Ergonomics Association, Human Factors and Sustainable Development (HFSD) the topic is a relatively new sub-sector related to ergonomics, it roots back to disciplines such as ecology, engineering, development studies and public health. HFSD does not limit to theoretical perspectives but approaches domains such as occupational risk prevention and workplace life quality. Further, integrating aspects such as innovative design, ergonomics and human factors enable ergonomic interventions that create value added not only for the organization but for the society, too. The paper aims to clarify the connections between ergonomics (human factors) and sustainable development.

*Key words:* Ergonomics, Sustainability, Reporting, Key Performance Indicators (KPIs).

---

### 1. Introduction

Integrating ergonomics in the sustainable development approach is a rare practice and the literature in the field do not make a clear presentation of any methodology. As for the International Ergonomics Association, Human Factors and Sustainable Development (HFSD) the topic is a relatively new sub-sector related to ergonomics, it roots back to disciplines such as ecology, engineering, development studies and public health. HFSD does not limit to theoretical perspectives but approaches domains such as occupational risk prevention and workplace life quality. Further, integrating aspects such as innovative design, ergonomics and human factors enable ergonomic interventions that create value added not only for the organization but for the society, too. In this context, the aim of the present paper is to clarify the connections between ergonomics (human factors) and sustainable development through the support of the knowledge (and approach) from the performance management domain. After some considerations on relationship between ergonomics and sustainability there will be analyzed the case of transparency of ergonomics in sustainability initiatives across companies. Thus, a proposed model for considering the Key Performance Indicators for reflecting the support of ergonomics in sustainable development will be proposed. Finally, some conclusions and remarks will be made.

### 2. Brief considerations on relationship between ergonomics and sustainability

It is not a novelty that ergonomics significantly contributes to employee wellbeing, generating major benefits for both the company and the society. Further, it became a common practice in the past years to adhere to sustainability targets and to report performance as per renowned models or principles. However, there is little evidence on how companies complement ergonomic activities with their sustainability and environmental initiatives. The reason behind this would be on the one hand, the design of the sustainability Key Performance Indicators (KPIs) and, on the other hand, lack of understanding on the interconnections between ergonomics and sustainability.

---

\* Corresponding author. Tel.: +40-256-403610; fax: +40-256-403610.  
E-mail address: boatcaelena\_2009@yahoo.com.

There has been little evidence of a clear connection between ergonomics and sustainability, despite their common aims of improving human well-being and generating benefits at individual, corporate and society levels. However, in the past decades there have been noticed steps taken towards highlighting the importance of ergonomics in achieving sustainability goals (Haslam and Waterson, 2013). International Ergonomics Association (IEA) established a Technical Committee dedicated to ‘Human Factors and Sustainable Development’, an innovative concept aiming to define and optimize the connections between ergonomics (human factors) and sustainability (Zink and Fischer, 2013). Considering the importance of IEA for the ergonomics global scientific and professionals’ community, this attempt indicates small steps towards coordinating sustainability with ergonomics.

To understand why this situation persists, Dekker (2013) research proved that “epistemological and ethical characteristics or ergonomics limit the validity of almost any ergonomic contribution to sustainability”. This research also brings to light a very interesting aspect: ergonomics, by itself, focuses on a problem-solving approach avoiding moral and social concerns that typically come up in sustainability debates. It is not that ergonomics wouldn’t be able to address more deep society concerns, but the way ergonomics is usually implemented is centered towards a specific problem, without necessarily addressing more “delicate” aspects related to ethics or whose interest is served (Dekker et al., 2013).

Leaving aside the prominent sustainability and ergonomics common interests, it is necessary a change of paradigm to define and approach ergonomics in its broader meaning. It is a feasible solution for development of ergonomics-specific KPIs that would be included in sustainability assessments of companies in the coming years, to obtain a more comprehensive understanding of the extent to which companies focus on their long-term impact on society.

### **3. Case study: transparency of ergonomics in sustainability initiatives across companies**

#### *3.1. Key Sustainability Rankings Globally*

There have been developed several initiatives to measure how companies commit to sustainability and, implicitly, highlight those companies that meet and exceed targets and performance. Nevertheless, these rankings bring in the spotlight large companies, capable of heavy investments and with the necessary know-how to implement sustainability measures. After all, these companies are the ones with the highest social and environmental impact.

The most important and renowned ranking is the one developed by Corporate Knights and United Nations Global Compact initiative. Corporate Knights is a Canada-based private company engaged in publishing of corporate responsibility magazine and sustainability-related rankings and reports. One of the most interesting rankings issued by the company is ‘Global Most Sustainable Corporations’, an annual ranking that highlights world’s most sustainable public companies based on objective assessment using a series of key performance indicators (KPIs), including the following:

- Energy productivity;
- Carbon productivity;
- Water productivity;
- Waste productivity;
- R&D/revenue;
- Cash taxes paid ratio;
- CEO-average worker pay ratio;
- Pension fund status;
- Injury rate;
- Fatalities number;
- Employee turnover rate;
- Women on board;
- Women executives;
- Sustainability pay link;
- Clean air productivity score;
- Supplier score;
- Clean revenue.

Additionally, each KPI is weighted to indicate the relative performance of the sector where the company activates. For example, the energy KPI would weight more in the case of a company operating in an energy-intensive sector (such as steel manufacturing, or oil and gas) as compared to a company operating in a sector that accounts for a smaller energy use rate.

Further, United Nations (UN) came with a sustainability initiative companies can adhere to: UN Global Compact. UN compiled a sustainability reporting system that enables any company to track certain KPIs across sustainability-related categories. The KPIs are compiled into ten principles derived from the Universal Declaration of Human Rights, the International Labor Organization’s Declaration on Fundamental Principles and Rights at Work, the Rio Declaration on Environment and Development, and the United Nations Convention Against Corruption.

The principles are as follows:

1. Support and respect the protection of internationally proclaimed human rights;
2. Make sure not to be complicit in human rights abuses;
3. Uphold the freedom of association and the effective recognition of the right to collective bargaining;
4. Eliminate all forms of forced and compulsory labor;
5. The effective abolition of child labor;
6. Eliminate discrimination in respect of employment and occupation;
7. Support a precautionary approach to environmental challenges;
8. Undertake initiatives to promote greater environmental responsibility;
9. Encourage the development and diffusion of environmentally friendly technologies;
10. Work against corruption in all its forms, including extortion and bribery.

Despite that major rankings measuring sustainability commitments of companies across the globe include parameters such as gender equality and equal payment across levels/countries, or diversity (referring to diversity of gender, ethnicity etc.), it is very difficult to quantify the extent to which ergonomics is a real part of the sustainability programs and strategies of each company included in the respective rankings. Further, parameters used to evaluate companies differ from a ranking to the other, and, hence, the companies included in one ranking do not appear in another although all these companies are supposed to be leaders in sustainability. This complicates even further any attempt to evaluate the extent to which ergonomics is truly a part of the company's long-term vision for employee well-being and overall sustainability.

From the above-mentioned KPIs, ergonomic-related metrics would only be injury rate and fatalities number. These two provide little information on how the company implements ergonomic interventions or what importance the company gives to ergonomics. Further investigations based on companies' sustainability reports and related documents might reveal further insights.

### 3.2. Analysis of transparency on ergonomic-related performance for top five sustainability leaders

The analysis is based on the Table 1 content of top five companies and their KPIs focused on environmental and financial performance.

Table 1. Top five sustainability leaders and their performance

Company:	Dassault Systemes	Neste Oyj	Valeo SA	Ucb SA	Outotec Oyj
Sector	Software	Oil, Gas & Consumable Fuels	Auto Components	Pharmaceuticals	Construction & Engineering
Country	France	Finland	France	Belgium	Finland
Energy Productivity Score	69.2%	66.9%	80.0%	92.3%	84.6%
Carbon Productivity Score	79.2%	78.6%	71.4%	94.0%	70.8%
Water Productivity Score	93.8%	74.1%	100.0%	92.6%	85.1%
Waste Productivity Score	95.0%	46.0%	58.3%	91.1%	88.7%
R&D/revenue 2014 - 2016	18.4%	0.3%	8.2%	26.2%	4.7%
Cash taxes paid ratio	26.5%	7.8%	12.2%	36.8%	36.6%
CEO-Average Worker Pay ratio	30	36	61	26	10
Pension Fund Status	65.2%	73.7%	59.3%	75.0%	60.6%
Injury rate	0.06	0.56	0.46	0.41	0.36
Fatalities number	-	-	-	-	-
Employee turnover rate	8.3%	11.2%	11.9%	16.0%	21.6%
Women on board	45.5%	42.9%	35.7%	30.8%	25.0%
Women executives	20.0%	18.0%	13.0%	27.0%	13.0%
Sustainability Paylink	100.0%	100.0%	0.0%	0.0%	100.0%
Clean Revenue (%)	25.0%	21.7%	40.0%	8.3%	65.0%
Clean Air Productivity Score	0.0%	57.5%	22.3%	0.0%	25.0%
Supplier Score	8%	24%	18%	14%	1%
Overall Score	86.13%	85.19%	83.59%	79.52%	78.27%

Considering the rankings, we have decided to focus on ‘Global Most Sustainable Corporations’ 2018 ranking as source of analysis on how companies report ergonomic-related initiatives as part of their sustainability efforts. Irrespective of the major social impact companies make when adhering to UN Global Compact reporting system, the ten principles do not serve the scope of this study. Consequently, we decided to leave aside leading companies included in Global Compact 100, a stock index that highlights sustainability performance in correlation with financial performance of the analyzed company.

Table 1 presents performance of top five companies across a variety of KPIs that are primarily focused on environmental and financial performance. However, injury rate and fatalities number provide a picture of how these companies perform in terms of ergonomics. While injury rate is relatively low, a positive sign is the absence of fatalities.

Based on the collected data, it has been observed that majority of the KPIs focus on the companies’ performance on environmental, economic and social aspects, without properly highlighting at least more detailed occupational health and safety-related commitments. This does not implicitly denote that the company does not measure these aspects, but their absence from the assessment of sustainability performance leads to lack of clarity on any potential indicators of how each company approaches ergonomics.

Furthermore, analyzing the five companies’ reports and publications on sustainability leads too little to no evidence on how these address ergonomic challenges of if they consider ergonomics as part of their sustainability efforts.

Coming back to the purpose of the paper, it is very difficult and inaccurate to analyze the relationship between sustainability and ergonomics based only on injury rate and fatalities number. This confirms, again, the hypothesis that ergonomics is not regarded as an essential parameter of sustainability, despite its major importance for achieving good occupational health and safety performance and generating a positive social impact.

#### 4. Proposed KPIs for characterizing the role of ergonomics in sustainable development

The new group of sustainability KPI was developed based on the concept and literature review as shown in Table 2.

Table 2. Proposed KPIs including the ergonomics support for sustainable development of the industrial system (extended from Helleno et al, 2017)

Dimension	Proposed KPIs	Description of the sub-indicators
Economic	Cost Management	Costs (equipment, materials and services); Acquisition; Return on Investment (ROI)
	Corporate Management	Competitiveness; Tools of Corporate Management; Strategic planning process; Market Share; Number of Recycled Material suppliers
	Operational efficiency	Cycle time; Lean manufacturing waste; Set-up time; Flexibility; Inventory and Stock; Quality of products and services; Total Quality Management (TQM)
	Products	New products; Innovation and insertion in international markets; DFMA (Design for Manufacturing and Assembly)
	Operating Results	Profits; Price; Operational Indicators.
	Suppliers	Standards for Supplier; Just-in-time; Delivery
	Customers	Number of complaints per customer/region; Deadline
	Infrastructure	Proximity to transportation hubs; Alternative transport availability; Availability of storage facilities; Efficient use of transport resources; Available manufacturing facilities
Social	Economic	Salary and benefits
	Satisfaction Level	Level of Employee satisfaction; Absenteeism; Turn Over
	Quality and Health	Health and Safety Programs; Ergonomics; Average distance travelled by employees to the company
	Human Resources	Availability of labor, skilled labor; Recruitment and selection; Hours of training; Performance evaluation (for employees)
	Community	Corporative philanthropy; public health; community development
Environment	Environmental Management	Policy/Environmental Standards; Indicators and Environmental Goals; Structure Responsible for the Environment; Monitoring Biodiversity; Voluntary disclosure of information on environmental performance
	Environmental Aspects	Environmental Aspects and Impacts; Supplier relationship with the environment; Company image in relation to the Environment
	Responsibility	Treatment/Disposal of Waste; Consumption of hazardous materials
	Consumption	Water, energy and paper
	Product life cycle	Product Lifecycle analysis
	Recycling	3 Rs (Reduce, Reuse, Recycle) Culture



The scope of the approach is to develop a conceptual method of assessment of sustainable development for industrial processes. This is separated into two distinct parts: (1) a literature review regarding sustainable indicators (considering the above mentioned aspects) and (2) the definition of sustainability indicator groups that compose the assessment method. The proposed approach aimed to define a new group of sustainability indicators (Economic, Environmental and Social KPIs), which must reflect also, the ergonomics efforts of the company. This will generate a conceptual method for assessing sustainability in the case of industrial processes. The integration of ergonomics with sustainability indicators was based on the research approach and results presented by Kuhlman et al. (2011) and Faulkner and Badurdeen (2014). The selection of sustainability indicator has followed the concept of Triple Bottom Line, considering the three dimensions of sustainability as suggested by (Helleno et al., 2017).

The focus was most on social KPIs dedicated to Quality and Health sub-indicators, where the ergonomics intervention and support are much helpful and visible. This development aims to contribute to the current sustainability assessment methods with a group of indicators that measure the parameters that can be improved by an ergonomics intervention and that influence the productivity and thereby promote the improvement of sustainability. In addition, ergonomics was considered a source for continuous improvement of the production system.

Previous researches in this field have been presented by (Lee et al., 2014; Brown et al., 2014) that have analyzed changes in production systems and services towards sustainable solutions, and they highlighted the need to develop methods to measure the levels of sustainability of manufacturing processes, but they do not detail ergonomic indicators. The proposed indicators related to the social dimension of sustainability were related to work safety, ergonomic aspects and level of noise, but only at the declarative manner.

In the context of our research, the proposed indicators in the Quality and Health sub-indicator are:

Health and Safety Programs (HSPr) [no. of existing/on-going programs in the assessment period];

$$HSPr = \text{No. of health programs} + \text{No. of safety programs} \quad (1)$$

This indicator is relevant for the prevention management related to OHS in the organization. It could be determined also, by reporting the number of OHS programs to the number of employees (NEO) to see if all them were involved in such programs.

$$HSPr = (\text{No. of health programs} + \text{No. of safety programs}) / NEO \quad (2)$$

Accident Rate (ARa) [accident in the assessment period]:

$$ARa = NA / NEO \quad (3)$$

In equation (3) there have been used the following notations: NA - number of accidents; NEO - number of employees. The relative ARa is inversely related to the ARa (1-ARa).

In the same way there have been defined the Occupational illness Rate (HRa) [new cases of occupational illness in the assessment period]:

$$HRa = NI / NEO \quad (4)$$

In equation (4) there have been used the following notations: NI - number of new illnesses cases in the assessment period; NEO - number of employees. The relative HRa is inversely related to the HRa (1-HRa). From the literature review point of view, indicators (3) and (4) reflects the quality of the professional life and the maturity level of the occupational health and safety system in the organization.

For the Ergonomics aggregate indicator (ERGO), average per NEO, there have been choose the definition inspired by the RNUR method (Draghici, 2004; Vasiliu and Bordei 2013; da Silva et al., 2016):

$$ERGO = \text{Postural} + \text{Physic ambience} + \text{Psychological stress} \quad (5)$$

The notations used in equation (5) are: Postural represent the cumulative scores for the physic load factors score (posture, work effort, handling effort); Physic ambience – cumulative score for thermal ambience, sound ambience, artificial lightning, vibration, air quality, workplace design; Psychological stress - cumulative score for mental task, autonomy, work relationship, repetitivity of work tasks and work content. The aggregate indicator Ergonomics need a special attention from the ergonomic team in the organization because of the permanent evaluation of each factors considered in equation (5) and the regulations for each of them.

Average distance travelled by employees to the company (Dtr):

$$Dtr = \text{Total distance travelled by employees to the company} / NOE \quad (6)$$

This indicator could adjust the way employees travel from their home location to the company and back and avoid accident occurrence (providing a unique safety transport system by the company).

## 5. Conclusions

Building a bridge between ergonomics and sustainability is not impossible but requires efforts from both sustainability-related organisms and companies committed to becoming sustainable. A major aspect that needs to be taken care of is development of ergonomic-related KPIs that would accurately reflect companies' commitment to both ergonomics and sustainability. Currently, the only KPIs that might be considered as ergonomic-related are occupational health and safety indicators such as number of injuries (or injury rate) and number of fatalities. These do not offer any transparency or understanding of how a certain company performs in terms of ergonomics.

Hoping that global initiatives aimed at constantly improving measurement of sustainability commitments will understand the significance of ergonomics, the only thing that remains on the shoulders for ergonomists is changing the way we regard ergonomics and expand its applicability across innovative fields and more 'delicate' aspects (such as business ethics).

The presented set of KPIs proposed for the social dimension of sustainability can be considered in organizations' practice. There have been agreed that for better reflecting the ergonomics efforts, an aggregate indicator could be used to assess and continuously monitor the physical load factors, the physical ambient conditions and the level of psychological stress factors. The proposed aggregate indicator Ergonomic should be determined using the RNUR method adapted and adjusted to the specific context of the organization.

Future researches will be focused on the practical demonstration of the proposed schema for integrating ergonomics and sustainability to prove the usefulness of this approach for the continuous improvement of organization's sustainable development.

## References

- Brown, A., Amundson, J., Badurdeen, F., Sustainable value stream mapping (Sus-VSM) in different manufacturing system configurations: application case studies, *Journal of Cleaner Production*, Vol. 85, pp. 164-179, (2014).
- da Silva, M. P., Tortorella, G. L., Amaral, F. G. Psychophysical Demands and Perceived Workload—An Ergonomics Standpoint for Lean Production in Assembly Cells. *Human Factors and Ergonomics in Manufacturing & Service Industries*, Vol. 26, No. 6, pp. 643-654, (2016).
- Dekker, S. W., Hancock, P. A., Wilkin, P., Ergonomics and sustainability: towards an embrace of complexity and emergence, *Ergonomics*, Vol. 56, No. 3, pp. 357-364, (2013).
- Draghici, A., Man—Machine System Re-Design from the Ergonomics Perspective, In *Methods and Tools for Co-operative and Integrated Design*. Springer, Dordrecht, pp. 45-56, (2004).
- Faulkner, W., Badurdeen, F., Sustainable Value Stream Mapping (Sus- VSM): methodology to visualize and assess manufacturing sustainability performance, *Journal of Cleaner Production*, Vol. 85, pp. 8-18, (2014).
- Haslam, R., & Waterson, P., Ergonomics and sustainability, *Ergonomics*, Vol. 56, No. 3, pp. 343-347, (2013).
- Helleno, A. L., de Moraes, A. J. I., Simon, A. T. Integrating sustainability indicators and Lean Manufacturing to assess manufacturing processes: Application case studies in Brazilian industry, *Journal of Cleaner Production*, Vol. 153, pp. 405-416, (2017).
- Kuhlang, P., Edtmayr, T., and Sihm, W., Methodical approach to increase productivity and reduce lead time in assembly and production-logistic processes, *CIRP Journal of Manufacturing Science and Technology*, Vol.4, No. 1, pp. 24-32, (2011).
- Lee, J. Y., Kang, H. S., Do Noh, S. MAS2: an integrated modeling and simulation-based life cycle evaluation approach for sustainable manufacturing, *Journal of Cleaner production*, Vol. 66, pp. 146-163, (2014).
- Vasiliu, A., Bordei, M. (2013). RNUR Method of Risk Assessment Based on Ergonomic Criteria. Case Study: Crane Maintenance Electrician.
- Zink, K. J., Fischer, K., Do we need sustainability as a new approach in human factors and ergonomics? *Ergonomics*, Vol. 56, No. 3, pp. 348-356, (2013).

## “Pro-Integra” project's comparative survey of main stakeholders' opinions on the educational offer of "1 Decembrie 1918" University of Alba Iulia

Călina-Ana Buțiu\*

*"1 Decembrie 1918" University of Alba Iulia, 15-17 Unirii Street, Alba Iulia, 510009, Romania*

---

### Abstract

The creation of tertiary-level educational opportunities is a stated objective of both European and national policies. More and more policy makers see stakeholders' opinions becoming more and more valuable. "1 Decembrie 1918" University of Alba Iulia's "Pro-Integra" project analyzes both the convergence and the divergence of program choice opinions among educators, students and administrative personnel in an open market economy. The understanding of these motivations helps improve the relevance and quality of the educational offer and helps attract candidates with promising development potential.

*Keywords:* tertiary education, social inclusion, stakeholders, opinions, intervention

---

### 1. Introduction

In the knowledge economy of today education becomes key to the development of human capital and governments around the world are placing it at the centre of their economic and social policy concern. Furthermore, education is not just important to developing economic competitiveness, but is also crucial to fostering active citizenship, social cohesion and international cooperation. There are nevertheless educational inequities, which, as they become more and more aware of, governments are trying to address through a diversification of programs. They are confronted with a dilemma: should they accept the education inequities as an unavoidable 'fact of life' and forego the wasteful costs their handling comes with or should they pursue intervention, in the hope they will eventually go away? An adequate answer to this dilemma does not seem to exist yet (Power, 2012, p. viii).

Frاندji (2012) notes that a series of issues like questions about the welfare state, changes in the business world and their implications for the educational system, the emergence of a new market logic and of new forms of school policy regulation, the concern for social stability and the demands for group recognition, they all require a rethinking of priorities in educational policy-making.

While inclusive education is not exactly a new concern, it does nevertheless require periodic rethinking (Slee, 1998, Waitoller and Artiles, 2013). Several studies ask for changes in educational policy and practices for students with disabilities and learning difficulties (Norwich, 2002, Bond and Castagnera, 2006, Schmidt and Venet, 2012, McGhie-Richmond et al., 2013), for students coming from underprivileged backgrounds (Cremin and Thomas, 2005, Palardy, 2013), or for students with diverse cultural or linguistic backgrounds (Artiles et al., 2006). The fact that each student has particular needs requires a most individualised strategy to the didactic approach and a redesign of the general curriculum accordingly (Howery et al., 2013).

Another series of works examine the multitude of factors, aside from the personal ones, leading to academic dropout. To the traditional sets of factors like race/ethnicity, gender, socio-economic, etc as *social background*, skills, abilities, test scores, etc. as *academic background* and school engagement, school grades, course completions and failures as *academically related behaviours*, Lee and Burkam (2003) also add factors of organizational nature. Their conclusion is that small universities with more positive student-professor relationships are facing less academic dropout. Similarly, Heck and Mahoe (2006) found that aside from personal and social factors, the organizational qualities of

---

\* Corresponding author. Tel.: +40-258-813-994; fax: +40-258-806-126, E-mail address: butiu.calina@uab.ro

schools have a decisive influence on the probability of graduation. Noticing that even the well-performing students sometimes abandon studies, Belloc et al, (2010) argue that it may be a "consumer-oriented" type of behaviour (p.137) reaching a point where they feel they are being sold a product they don't really need, i.e. a study program unsuitable to their interest.

## 2. Stakeholders in the *Pro-Integra* Project

The Pro-Integra project undertaken by "1 Decembrie 1918" University of Alba Iulia has as stated goals the increase in the student-at-risk inclusion capacity of the academic institution and the development of an equity-improvement educational strategy. Part of the project also included a Research and Territorial Development Centre-tested and validated methods-based *social intervention* application. The *results restitution* method used determines social behavioural change among social actors once more in-depth knowledge of problematic features becomes available (Pascaru and Butiu, 2007).

During the research stage, three successive surveys were taken, data being collected through standardised questionnaires from the three groups considered representative for the goal of the project: 1038 students, 61 faculty members (teachers) and 38 administrative subjects. The following phase included group interviews, one for each of the representative group. The research stage was followed by interventions based on the results interpretation, achieving thus in a relatively short period of time, a series of sustained and interconnected activities of great intensity and institutional scope, involving diverse stakeholders (Table 1).

Table 1. Stakeholders and specific activities in *Pro-Integra* project

Stakeholders	Activities
Students	Survey response
	Group interview participation
	Training
	Counselling session participation
	<i>INTEGRA platform interaction</i>
Faculty	Research on the issue of equity in education
	Survey response
	Group interview participation
	Curricula modification proposals
	<i>INTEGRA platform interaction</i>
Career counsellors	Training
	At-risk students' socio-occupational counselling and orientation
	Student training on INTEGRA platform use
	<i>INTEGRA platform interaction</i>
Administrative staff	Training
	<i>INTEGRA platform interaction</i>
Managers	Access and Social Equity Strategy for 2016-2020 of the "1 Decembrie 1918" University of Alba Iulia
	Access and Social Equity Strategy Implementation Plan for 2017

Source: Butiu, 2017, p. 9.

## 3. Comparative stakeholders' opinions on educational offer

Educational offer in the context of the current study refers to a wide set of facilities, including not only the choice of academic programs, but also those aspects that complete and support the educational act and which can become the object for improvement intervention.

The main stakeholders (students, faculty and administrative personnel) were asked questions both specific to their area of interest and to each competences, and questions common to all categories. This allowed for a comparative study of different perspectives. One question queried the specific advantages of the "1 Decembrie 1918" University of Alba Iulia (UAB). The answers showed that while students take the educational offer to be the most important reason for choosing the school, 93% of faculty and 60% of administrative personnel have more appreciation for the public nature of the institution (Table 2). Access and location are more important to faculty and administrative personnel than to students and also the lower living costs, which 82% of faculty see them as a critical edge over other cities; only 56.6% of students and 56.7% of administrative staff consider them important. The conditions for study and the quality of the facilities are also in higher regard by faculty than by students or by administrative personnel, and finally the prestige of the school, although chosen by less than half of the students, is nevertheless more appreciated by students (40.8%) than by faculty (34.4%) or administrative staff (35%).

Table 2. Opinions on „1 Decembrie 1918” University's advantages (%)

UAB Advantage	Students	Faculty	Admin. Personnel
Access	33.0	60.7	50.0
Tuition	35.2	62.3	58.3
Location	53.2	77.0	38.3
Costs compared to other cities	56.6	82.0	56.7
Educational offer	80.7	54.1	48.3
Being a public institution	65.2	93.4	60.0
Conditions and the quality of facilities	57.0	73.8	58.3
Prestige	40.8	34.4	35.0

In order to design the most suitable interventions one also queried students' (S) and faculty's (F) degree of satisfaction with the educational aspects, and administrative personnel's awareness of these aspects. The data in Table 3 shows differences of opinions on some aspects and less divergence on others. Aggregating the "Satisfied" and "Very Satisfied" answers shows students being overall more satisfied than faculty members with all but two of the aspects, the top being the theoretical knowledge acquired (90.1%) followed by the quality of the facilities (85.1%), whereas teachers are substantially more satisfied with the time schedule (91.8%), in spite that this ranks low on students' satisfaction list. The result reflects the reality that most scheduling is done primarily around teachers' effort to fit in lecturing and seminars with lab, consulting, student counselling and academic research work. Under the "very satisfied" rank alone, both students and faculty score most frequently teacher's availability to discuss their problems (40.2%) and 29.5% respectively. Also noticeable is that while ranking high on the theoretical knowledge, the university is ranked low by both groups on supplying practical knowledge. These findings were useful to the development of the Pro-Integra technology platform, which has been fitted with a modern, user-friendly, intuitive interface to its *Communication* and *Counselling* modules.

Table 3. Students and Faculty's degree of satisfaction with educational aspects at UAB (%)

Concerning "1 Decembrie 1918" University of Alba Iulia, to what extent are you satisfied with...?	Very Satisfied		Satisfied		Total of Satisfied and Very Satisfied		Little Satisfied		Unsatisfied		Total of Unsatisfied and Little Satisfied		N/A
	S	F	S	F	S	F	S	F	S	F	S	F	
	S	F	S	F	S	F	S	F	S	F	S	F	
Theoretical knowledge acquired	33.7	27.9	56.4	59	90.1	86.9	6.3	9.8	0.8	0	7.1	9.8	2.9
Practical knowledge acquired	25.5	11.5	47.3	52.5	72.8	64	17	32.8	5.1	1.6	22.1	34.4	5.1
Time schedule	28.4	26.2	48.8	65.6	77.2	91.8	15	6.6	2.9	0	17.9	6.6	4.8
Facilities (libraries, labs etc.)	34	26.2	51.1	54.1	85.1	80.3	8	16.4	1.1	1.6	9.1	18	5.9
Student's chances for employment after graduation	20.6	18	48.7	45.9	69.3	63.9	22.8	26.2	2.9	8.2	25.7	34.4	4.9
Teaching methods	36.2	16.4	46.7	57.4	82.9	73.8	11.1	14.8	1.6	8.2	12.7	23	4.3
Teachers' availability for students' problems	40.2	29.5	40.1	57.4	80.3	86.9	11.8	9.8	3.2	1.6	15	11.4	4.8

There are noticeable differences in the degree of administrative staff awareness of the same educational aspects (Table 4). As expected, they are better informed about facilities and time schedules - to which they have direct access - than about teaching methods. What is less expected is their claim to be fairly informed of the availability of teachers to discuss students' problems and of the theoretical knowledge acquired. Where they clearly lack awareness is on the student's chances for employment after graduation (60.5%).

Table 4. The level of administrative personnel's information on educational aspects at UAB (%)

When thinking of the specialisations offered by "1 Decembrie 1918" University of Alba Iulia, how much information you have on...?	Very much	Much	Little	None
Theoretical knowledge acquired	7.9	44.7	36.8	10.5
Practical knowledge acquired	5.3	34.2	50	10.5
Time schedule	26.3	18.4	42.1	13.2
Facilities (libraries, labs etc.)	39.5	52.6	7.9	0
Student's chances for employment after graduation	5.3	31.6	60.5	2.6
Teaching methods	10.5	23.7	55.3	10.5
Teachers' availability for students' problems	18.4	50	23.7	7.9

## Conclusions

In stakeholders' opinions intervention is justified for both ethical and effectiveness reasons. In a vicious (or virtuous) circle, opinions are anchored in attitudes and lead in turn to attitudes. The objective of Pro-Integra's project, as that of many other tertiary educational inclusion projects, was to enhance the chances for participation to university education of young students. The identification of both convergences and divergences of opinions on the significant drivers for student access to and success in education was both the starting and the pivotal point of the project. Finding out main stakeholders' perspectives has helped initiating those actions needed to both form and inform. Faculty learned that student's perspective is different from theirs and students in turn got to better understand what their educators' consider to be the most important aspects of the educational act. The most valuable finding perhaps was the need for raising the awareness of the administrative staff of the needs of the students and in general, of a more effective communication with the administrative department; the Pro-Integra information technology platform was implemented to facilitate that. The project helped with the understanding that the different roles of teachers and administrators should not lead to divergent positions and that they are both contributing to the educational process with different instruments. Notwithstanding the different motivations they are driven by, the final purpose of the project should be improved student access to higher education.

## Acknowledgements

The Pro-Integra project has been financed through a 2016 CNFIS-FDI grant. While management and implementation teams are hereby credited and appreciated for their effort, it should nevertheless be said that the project, with its wide range of research and intervention activities, was a collective effort of many academic, technical, financial and logistical contributors whose list is too long to be spelled-out here in detail.

## References

- Artiles, A., Harris-Murri, N., Rostenberg, D., Inclusion as Social Justice: Critical Notes on Discourses, Assumptions, and the Road Ahead. *Theory Into Practice*, 45(3), pp. 260-268, (2006).
- Belloc, F., Maruotti, A., Petrella, L., University drop-out: An Italian experience, *Higher Education*, 60(2), pp. 127-138, (2010).
- Bond, R., Castagnera, E., Peer Supports and Inclusive Education: An Underutilized Resource, *Theory Into Practice*, 45(3), pp. 224-229, (2006).
- Buțiu, C.-A., Evidence based practice in academic dropout policy. The Pro-Integra model, *Journal of Community Positive Practices*, Nr. 1/2017, pp. 3-12, (2017).
- Cremin, H., Thomas, G., Maintaining Underclasses via Contrastive Judgement: Can Inclusive Education Ever Happen? *British Journal of Educational Studies*, 53(4), pp. 431-446, (2005).
- Frاندji, D., Introduction: Toward a Comparison of Priority Education Policies, Europe, *Educational Policies and Inequalities in Europe*, Marc Demeuse, Daniel Frاندji, David Greger, Jean-Yves Rochex eds., Palgrave Macmillan, pp. 1-22, (2012).
- Heck, R.-H., Mahoe, R., Student Transition to High School and Persistence: Highlighting the Influences of Social Divisions and School Contingencies, *American Journal of Education*, Vol. 112, No. 3 (May 2006), pp. 418-446, (2006).
- Howery, K., McClellan, T., Pedersen-Bayus, K., "Reaching Every Student" with a Pyramid of Intervention Approach: One District's Journey, *Canadian Journal of Education / Revue canadienne de l'éducation*, Vol. 36, No. 1(2013), pp. 271-304, (2013).
- Lee, V., Burkam, D., Dropping out of High School: The Role of School Organization and Structure, *American Educational Research Journal*, 40(2), pp. 353-393, (2003).
- McGhie-Richmond, D., Irvine, A., Loreman, T., Lea Cizman, J., Lupart, J., Teacher Perspectives on Inclusive Education in Rural Alberta, Canada, *Canadian Journal of Education / Revue Canadienne De L'éducation*, 36(1), pp. 195-239, (2013).
- Norwich, B., Education, Inclusion and Individual Differences: Recognising and Resolving Dilemmas, *British Journal of Educational Studies*, 50(4), pp. 482-502, (2002).
- Palardy, G., High School Socioeconomic Segregation and Student Attainment, *American Educational Research Journal*, 50(4), pp. 714-754, (2013).
- Pascaru, M., Buțiu, C.-A., Restituirea rezultatelor și detvoltarea cpmunitară, Argonaut, Cluj-Napoca, (2007).
- Power, S., Foreward, *Educational Policies and Inequalities in Europe*, M. Demeuse, D. Frاندji, D. Greger, J-Y. Rochex eds., Palgrave Macmillan, pp. i-x, (2012).
- Schmidt, S., Venet, M., Principals Facing Inclusive Schooling or Integration, *Canadian Journal of Education / Revue Canadienne De L'éducation*, 35(1), pp. 217-238, (2012).
- Slee, R., Inclusive Education? This Must Signify 'New Times' in Educational Research, *British Journal of Educational Studies*, 46(4), pp. 440-454, (1998).
- Waitoller, F., Artiles, A., A Decade of Professional Development Research for Inclusive Education: A Critical Review and Notes for a Research Program, *Review of Educational Research*, 83(3), pp. 319-356, (2013).
- Weiss, C., Bearman, P., Fresh Starts: Reinvestigating the Effects of the Transition to High School on Student Outcomes. *American Journal of Education*, 113(3), pp. 395-421, (2007).

## Financing the development of the city of Opole based on its budget

Dariusz Rajchel<sup>a\*</sup>

*<sup>a</sup>Opole University of Technology, Faculty Economics and Management, 45-758 Opole, Prószkowska 76, Poland*

---

### Abstract

The city's budget is the most important financial document including income and expenses for statutory tasks (obligatory) and optional one. Cities dispose of a largest financial resources, therefore, local authorities decisions should contribute to their cultural and socio-economic development to improve the quality of life of citizens. The purpose of the paper is to show the funds spent for tasks that have a significant impact on the development of the examined unit in Opole city's budget.

*Keywords:* Opole, budget, finances, developments

---

The budget of the local government unit (LGU) in accordance with art. 211. The Public Finance Act (Act of 27 August 2009 on public finance) is an annual plan of income and expenditure, as well as revenues and outlays of this unit, adopted for the fiscal (calendar) year in the form of a budgetary resolution that is the basis for the financial management of a local government unit in a given budget year. The budgetary resolution consists of the budget of the local government unit and annexes.

Recognized local government units in Poland are the commune, county, and voivodship as a regional level. The city according to art. 2, point 3 of the Act on official names of towns and physiographic objects (Act of 29 August 2003 on the official names of towns and physiographic objects) is a settlement unit with a predominance of compact buildings and non-agricultural functions, having city rights or city status granted in the mode specified in separate legal regulations. However, in art. 4, item 1 point 2 of the Local Government Act (Act of 8 March 1990 on local government), there is a provision: The Cabinet Council, in the form of regulation, gives the commune or town the status of a city and sets its limits.

When discussing the budget of LGU including a town, it is important that potential sources of financial support for local government authorities include:

a) own income - most often understood as income which, according to the various Acts and regulations, is permanently given to the local government authorities, including shares in central taxes, income from local taxes, fees for various services, income from property rights, income from the sale of property,

b) compensatory income - it is primarily transfers from state authorities to local authorities in the form of subsidies, subsidies,

c) earnings (revenues) from loans (Owsiak, 2017).

In addition to the LGU budget revenues listed above, there are also potential revenues such as: funds from non-refundable foreign sources, funds from the European Union budget and other funds specified in separate legal regulations (Owsiak, 2017).

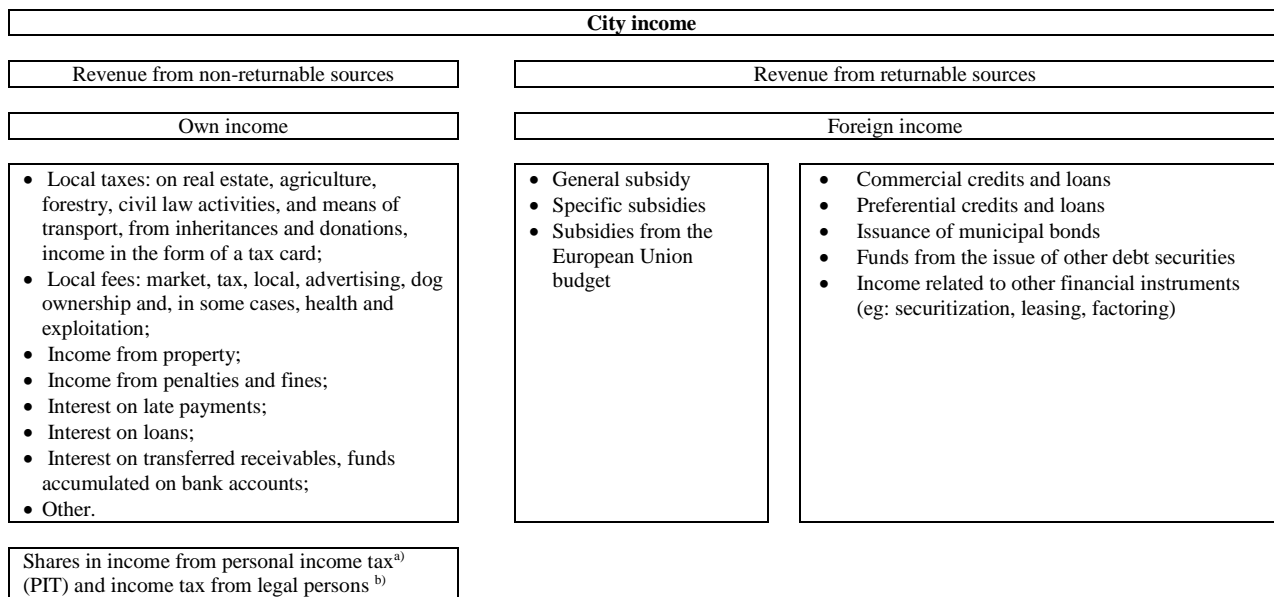
The budget of the local government unit is a reflection of the general socio-economic situation and the expectations of local residents of spending funds on key undertakings for the city, commune, county or voivodship. Cities have the largest financial resources, therefore decisions made by local authorities should contribute to their socio-economic and cultural development, to improve the quality of life of residents.

The aim of the article is to show the financial resources spent within the city budget of Opole on tasks having a significant impact on the development of the examined unit.

---

\* Dariusz Rajchel  
E-mail address: d.rajchel@po.opole.pl

Income of the commune, including the city, are defined in art. 3 of the Act on revenues of local government units (Act of November 13, 2003 on revenues of territorial self-government units). The classification of city income is shown in Diagram 1.



a) The Ministry of Finance informs that the share of communes in income from personal income tax, determined in accordance with the principles set out in Art. 9 section 1 in connection with Article 89 of the Act of 13 November 2003 on the incomes of local government units (Journal of Laws of 2016, item 198, as amended), in 2018 will amount to 37.98%

b) The amount of share in income from corporate income tax, from taxpayers of this tax, with registered office in the area of the commune, is 6.71%.

Figure 1 Income of cities in Poland

Source: Act of November 13, 2003 on revenues of local government units (Journal of Laws 2003 No. 203, item 1966, as amended) and Z. Przygodzki, *Finansowanie rozwoju miasta*, [w:] *EkoMiasto# Gospodarka. Zrównoważony, inteligentny i partycypacyjny rozwój miasta*, pod red. A. Nowakowskiej, Wydawnictwo Uniwersytetu Łódzkiego, Łódź 2016, p. 129.

According to art. 54, point 2 of the Act on municipal government, the income of the commune may also be revenue from self-taxation of residents. Self-taxation can only take place through a municipal referendum referred to in article 2, paragraph 2 point 2 of the Act of 15 September 2000 on the local referendum (The Act of 8 March 1990 on local government).

Presenting the income side of the city budget, it is also important to present their spending on specific goals, tasks and investments. The city's expenditures have been specified in art. 236 of the Public Finance Act. Expenditure of the city budget is shown in Diagram 2.

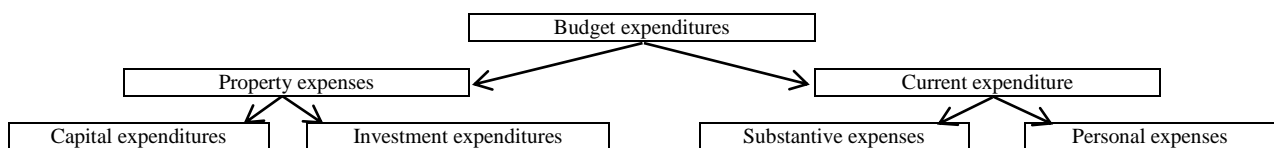


Figure 2. City budget expenditure

Source: Z. Przygodzki, *Finansowanie rozwoju miasta*, [w:] *EkoMiasto# Gospodarka. Zrównoważony, inteligentny i partycypacyjny rozwój miasta*, pod red. A. Nowakowskiej, Wydawnictwo Uniwersytetu Łódzkiego, Łódź 2016, p. 132.

Current expenditure of the budget of a local government unit including a city is understood as budget expenditure that is not expenditure on property. The current expenditure plan distinguishes planned amounts of current expenditure, in particular:

- 1) expenditure of budgetary units, including:
  - a) remuneration and contributions from them,
  - b) expenses related to the performance of their statutory tasks;
- 2) grants for current tasks;
- 3) benefits for individuals;
- 4) expenditure on programs financed with the participation of funds referred to in article 5 paragraph 1 points 2 and 3 (Act of 27 August 2009 on public finance), in part related to the implementation of tasks of the local government unit;
- 5) payments due to sureties and guarantees granted by the local government unit, to be repaid in a given budget year;
- 6) servicing the debt of a local government unit.



The plan of property expenditure distinguishes planned amounts of capital expenditure, which includes expenditure on:

- 1) investment and investment purchases, including programs financed with the participation of funds referred to in article 5 paragraph 1 points 2 and 3, in part related to the implementation of tasks of the local government unit;
- 2) purchase and assumption of stock and shares;
- 3) contribution to commercial law companies.

Opole is a city with county rights and, at the same time, the capital of the Opolskie Voivodeship which makes it the main city of the region. It is also an economic, administrative, cultural and education centre. By the decision of the Cabinet Council of 19 July 2016 and published in the form of a regulation (Regulation of the Cabinet Council of 19 July 2016 on establishing the boundaries of some communes and cities, granting some towns the status of a city and changing the name of a commune), from 1 January 2017 after joining the area from the neighbouring municipalities, Opole increased from 97 km<sup>2</sup> to 149 km<sup>2</sup> area. Before the change of administrative borders in Opole there were about 118 thousand residents and after the change, the number increased to over 128 thousand. Opole is a city with good road, rail and water connections. It is a key urban centre affecting the pace and dynamics of the development of the entire Opolskie Voivodeship.

This is reflected in the financial situation of the city, which is improving year by year. Based on the budget resolution, it can be stated that the city's income and expenses since 2014 show an increasing trend, as shown in Figure 3.

The budget resolution, in financial terms, is the basic document of city management. The City Council of Opole with resolutions and the President of the City with fiats may make the changes to the revenue and expenditure plan of the city budget plan because of overtaken activities.

As a result of the corrections made in the budget resolution of the city of Opole, the growing trend in individual areas of the city budget has been preserved since 2014. The most important is that, in December 31 of each year, budget implementation is being prepared, in which since 2015 budget surplus has been recorded at different levels, and so in 2015 the budget surplus amounted PLN 7 622 350.96, in 2016 it was PLN 3 036 099.16, and in 2017: PLN 2 886 225.92. The implementation of the budget for 2014-2017, on 31 December each year is presented in Figure 4.

The data presented in bot charts above show that the largest part of expenditures are current expenses amounting to approx. 87% of all expenditures, the remaining part is capital expenditure. In 2018, it is assumed that the expenses of the city of Opole will be respectively: current expenditure 69%, property expenditure 31%. In 2018, the city authorities plan to allocate the following financial resources to individual sectors. Figure 5 presents, in percentage terms, the funds spent for particular sectors.

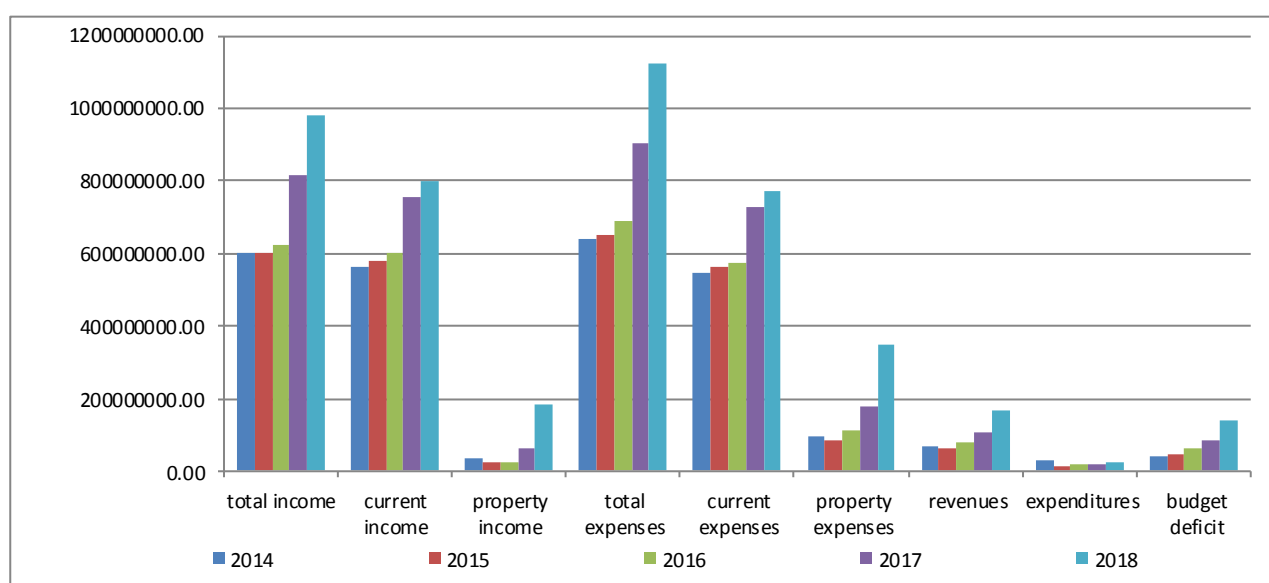


Figure 3. Planned income and expenditures as well as budget revenues and expenses in 2015-2018 based on adopted budget resolutions of the city of Opole

Source: own study based on the budget resolution of the city of Opole

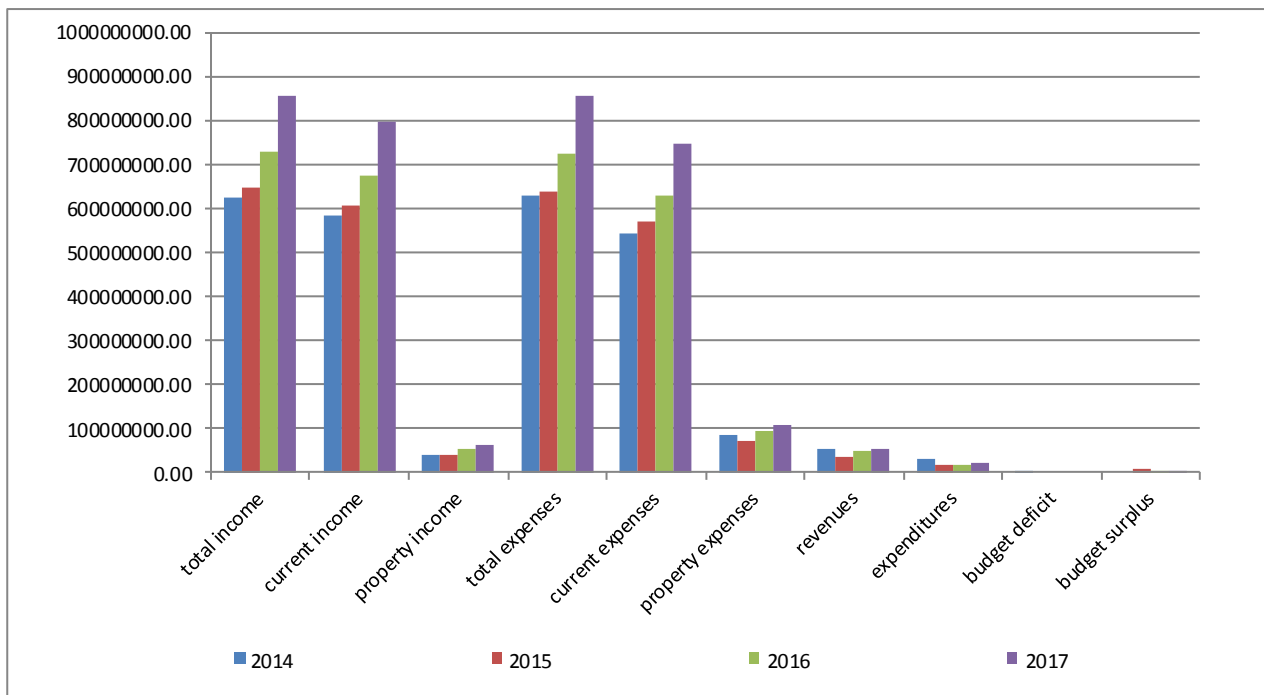


Figure 4. Implementation of the budget of the city of Opole for the years 2014-2017 on 31 December each year.

Source: own study based on the reports of the President of Opole on the implementation of the city budget of Opole for the years 2014-2017.

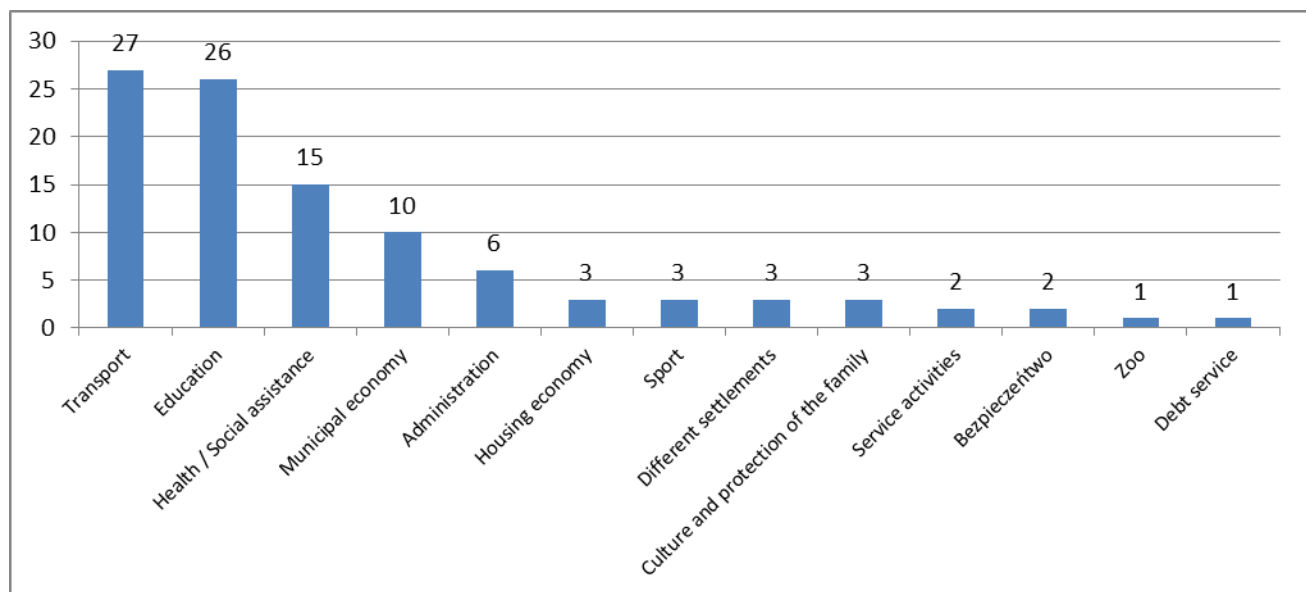


Figure 5. The most important expenses of the city of Opole in 2018, divided into areas

Source: R. Ćwirzeń-Szymańska, Skarbnik Miasta Opola, *Budżet miasta Opola w 2018 r.* [w:] *Budżet miasta Opola w 2018 r.*, A. Wiśniewski, Prezydent Miasta Opola, Urząd Miasta Opola z dnia 15 listopada 2017 r.

In accordance with the adopted budget resolution in 2018, the following financial resources are assumed for investment expenditures (Wiśniewski, 2017):

- culture - PLN 965 932 (modernization of cultural objects - value of the task: PLN 8 781 043),
- sport and recreation - PLN 10 260.28. (construction of sports fields and football pitches at schools - the value of the task: PLN 5 872 000 and PLN 200 000 were allocated to the competition concerning the concept of the new stadium),
- revitalization and monuments - PLN 11 876 330 (reconstruction of city squares - value of the task: PLN 8 065 632, revitalization of Krakowska street, two stages - value of the task: PLN 29 555 000. Former Opole - Upper Castle - value of the task: PLN 6 294 800),
- housing management - PLN 7 410 000. (purchase of land and real estate as well as construction of new apartments),
- service activity - PLN 15 840 000.
- reconstruction of roads and pavements - PLN 17 000 000.

- new bike paths - PLN 3 000 000.
- street lighting – 700 000 PLN.
- Opole East - PLN 20 320 000. (value of the task: PLN 182 620 624),
- Opole Zachód - PLN 17 033 305. (value of the task: 29 875 965 PLN),
- road in Żerkowice - PLN 7 957 195. (value of the task PLN 8 216 990),
- education - PLN 4 518 300. (support for vocational education - value of the task: PLN 5 429 047, reconstruction of the playground near the school - value of the task: PLN 50 000, purchase of computer equipment for schools – value of the task: PLN 500 000, modernization of the cloakroom and canteen at school - value tasks: PLN 220 000).

It is known that part of the investment is short-term and will end within one budget year, and some of them will require higher investment expenditures spread over time. Such investments include, for example, the reconstruction of the intersection of Oleska and Batalionów Chłopskich streets (Opole East), the cost of which is estimated at over PLN 180 million. The city office received as much as PLN 112 million for this investment from the governmental Operational Program Infrastructure and Environment 2014-2020. The project assumes:

- reconstruction of access roads to the intersection,
- creation of a double roundabout,
- construction of an underground passage for cars,
- construction of a flyover at the railway embankment and a tunnel in the embankment next to the Opole Wschodnie railway station,
- creation of a small bus station,
- creation of car parks and bike rentals.

The investment will be implemented in stages from 2018. Figure 6 presents the current state - before the implementation of the investment project (Guzik, 2018).



Figure 6. Intersection before the undertaking



Figure 7. Visualization of the intersection after completion of the investment

Source: Naszemiasto.pl, aktualizacja 23 lipca 2018 r. dostęp: <http://opole.naszemiasto.pl/arttykul/centrum-przesiadkowe-przy-stacji-kolejowej-opole-wschodnie,4735717,artgal,34107785,t,id,tm,zid.html>

Previous significant investments in Opole include the demolition of the old bridge and the construction of a new bridge in its place with a footbridge and bicycle path, a comprehensive modernization of Niemożlińska street with infrastructure replacement, construction of new pavements, bicycle paths, modernization of the "Okraglak" Sports and Entertainment Centre, construction of the "Politechnika" roundabout, renovation of the Amphitheatre and creation of the Polish Song Museum, reconstruction of roads, construction of green areas, investments in educational facilities and many other important for the development of the city and improving the lives of residents.

The effect of the investments is to improve and create infrastructure in every area of economic, social, service etc ... city life. Rational investment of financial resources by the city authorities ensures efficient functioning and development of the city (communes). Each local government unit, pursuing a specific policy, strives to gain a competitive advantage in terms of investment attractiveness. Acquiring entrepreneurs and creating new investments results in increasing the budget revenue of the commune, especially own income, from which it is possible to finance tasks serving the development of the local community (Nargiełło, 2006). The growing budget income of the city of Opole and its skilful and rational spending contributes to making further investments and further improving the living conditions of residents and city investors.

## References

- Ćwirzeń-Szymańska R., Skarbnik Miasta Opola, *Budżet miasta Opola w 2018r.* w: *Budżet miasta Opola w 2018r.*, A. Wiśniewski, Prezydent Miasta Opola, Urząd Miasta Opola (15 listopada 2017r.).
- Guzik P., *Centrum przesiadkowe przy stacji kolejowej Opole Wschodnie będzie kosztować ponad 136 mln złotych*, w: Naszemiaso.pl, dostęp: <http://opole.naszemiaso.pl/arttykul/centrum-przesiadkowe-przy-stacji-kolejowej-opole-wschodnie,4735717,artgal,34107785,t,id,tm,zid.html>, (23 lipca 2018r.).
- Nargiełło J., *Zdolność kredytowa jako element potencjału finansowego jednostek samorządu terytorialnego*, „Studia Regionalne i Lokalne” pp. 99-116, nr 3(25) (2006).
- Owsiak S., *Finanse publiczne współczesne ujęcie*, PWN, Warszawa, (2017).
- Przygodzki Z., *Finansowanie rozwoju miasta*, [w:] *EkoMiasto# Gospodarka. Zrównoważony, inteligentny i partycypacyjny rozwój miasta*, pod red. A. Nowakowskiej, Wydawnictwo Uniwersytetu Łódzkiego, Łódź, (2016).
- Wiśniewski A., Prezydent Miasta Opola, *Budżet miasta Opola w 2018r.*, Urząd Miasta Opola (15 listopada 2017r.).
- Act of 27 August 2009 on public finance, Dz.U. 2009 No. 157 item 1240 with later d.
- Act of 29 August 2003 on official names of towns and physiographical objects, Dz.U.2003 No. 166 item 1612 with later d.
- The Act of 8 March 1990 on local government, Dz.U. 1990 No. 16 item 95 with later d.
- Act of November 13, 2003 on revenues of territorial self-government units, Dz.U. 2003 No. 203 item 1966 with later d.
- Regulation of the Council of Ministers of 19 July 2016 on determining the boundaries of some municipalities and cities, granting some towns the status of a town and changing the name of a commune, Dz.U. RP Warsaw, 28 July 2016 item 1134.
- Resolution No. LII / 775/13 of the City Council of Opole of December 17, 2013 regarding the adoption of the budget of the city of Opole for 2014.
- Resolution No. IV / 9/14 of the City Council of Opole from December 18, 2014 regarding the adoption of the city budget of Opole for 2015.
- Resolution No. XIX / 337/15 of the City Council of Opole of December 17, 2015 regarding the adoption of the budget of the city of Opole for 2016.
- Resolution No. XXXV / 679/16 of the City Council of Opole of December 15, 2016 regarding the adoption of the city budget of Opole for 2017.
- Resolution No. LIII / 1065/17 of the City Council of Opole of December 15, 2017 regarding the adoption of the budget of the city of Opole for 2018.
- Reports by the President of Opole from 30 March 2015 on the implementation of the city budget of Opole for 2014.
- Reports by the President of Opole from 30 March 2015 on the implementation of the city budget of Opole for 2015.
- Reports by the President of Opole from 30 March 2015 on the implementation of the city budget of Opole for 2016.
- Reports by the President of Opole from 30 March 2015 on the implementation of the city budget of Opole for 2017.

## A graduate of a secondary school on the labour market. Chances and threats

Anna Rajchel<sup>a\*</sup>

*<sup>a</sup>Opole University of Technology, Faculty Economics and Management, 45-758 Opole, Prószkowska 76, Poland*

---

### Abstract

Dynamic and changing job market requires professional experience from employees. In the Polish education system, vocational education is provided by technical and industry schools. General secondary schools educate mainly potential students. Young graduates of these schools have no professional preparation. The selected class profiles do not give them any rights. However, those young people have a large theoretical knowledge and that can be used in many industries consistent with their education and knowledge. When analyzing job offers for people with general secondary education, it often turns out that they are addressed to people who already have acquired some professional experience. Secondly, they are not always adequate to the education they ended.

*Keywords:* general secondary school, class profiles, job market, job offers

---

### 1. Introduction

Secondary schools are the ones that are very popular among young people. They prepare well for the secondary school-leaving exams and studies in specific directions. Students planning a professional career in such areas as medical, legal, pedagogical, etc. are choosing classes with profiles corresponding to their interests, further educational and professional plans. In 2018, the number of graduates of this type of schools amounted to 5367 people. In comparison to 2017, this number decreased by 610 people, and when compared to 2005 by 2964 people (Liczba absolwentów...). This situation may result from several reasons. One of them is demographic. Another reason is the change in the attitude of young people to education. Technical schools prepare for the school-leaving exam and performing a specific profession. During their education, students must complete compulsory placements which allow them to gain experience. General secondary schools, according to the assumptions in their curriculum do not offer such a chance. The emerging new class profiles, above all, tempt young people with high pass rate of school-leaving exams, cooperation with universities, the possibility of pursuing specific educational projects, participation in workshops that bring them closer to a particular profession. These schools offer a great number of development opportunities. Young people, depending on the chosen class profile, have classes in subjects that are most often introduced during studies. This is, for example, psychology, medicine, dietetics etc. Extra classes are being implemented in many areas, thanks to which young people can better prepare for the school-leaving exam. However, the situation of young graduates of general secondary schools in the labour market (especially those who have not passed the school-leaving exam) is not easy. These are young people without any experience and professional preparation. They are yet to get them. For them it is the beginning of their professional career.

The article presents profiles of education in selected general secondary schools in Opolskie Voivodeship and job offers offered to the graduates of these schools. There is an attempt undertaken to show that these offers are not always adequate for the education of job applicants. They are usually directed to people who already have certain skills and professional experience. Young people who have just graduated secondary school and have only secondary education, are open to acquiring new skills and improving their qualifications. They are good employees who can prove themselves in various fields, but adequate to their education and capabilities.

---

\* Anna Rajchel  
E-mail address: a.rajchel@po.opole.pl

## 2. The structure of education in Poland

The education reform in force in Poland since 1 September 2017 introduced many changes in the education system for children and adolescents. According to art. 18 of the Act of December 14, 2016, *Prawo oświatowe*, public and non-public schools are divided into:

- 1) an eight-year primary school (previously 6-year primary school + 3-year lower secondary school),
- 2) post-primary schools:
  - a) four-year secondary school (previously 3-year)
  - b) a five-year technical college (previously 4-year)
  - c) three-year industry school of the first degree (previously 3-year basic vocational school)
  - d) a three-year special training school for employment,
  - e) a two-year industry school of the second degree,
  - f) post-secondary school for people with secondary or secondary industry education, with a teaching period of no more than 2.5 years (The Act of December 14, 2016 *Prawo oświatowe*).

Figure 1 shows the structure of education in Poland.

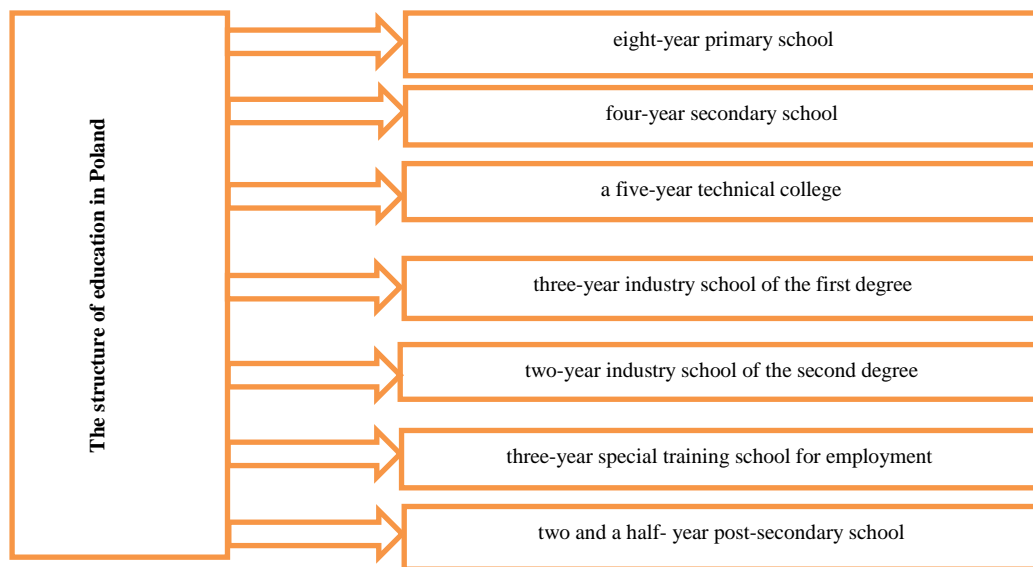


Figure 1. The structure of education in Poland

Source: Own study based on art. 18 acts from December 14, 2016. *Prawo oświatowe oraz Nowa struktura szkolnictwa w Polsce*, <https://www.nowaera.pl/strona-glowna/reforma-oswiaty-pod-lupa/nowy-ustroj-szkolny>

Children at the age of 7 start their education in a primary school. After completing education at this level of education, young people can choose a secondary school, technical college preparing for a school-leaving exam as well as for vocational exam, a 3-year industry first-degree school, which appeared in place of a basic vocational school. From September 1, 2020, the second-degree industry school will be launched, intended for graduates of the industry school of the first degree. In the first-degree industry school, young people will learn within one qualification (Regulation of the Minister of National Education of March 13, 2017 w sprawie klasyfikacji zawodów szkolnictwa zawodowego). Graduating the second-degree industry school allows its graduates to obtain the degree of a technician. The special education school is a special school designed exclusively for students with moderate or severe intellectual disabilities and for students with disabilities (Article 18 point 2 of the Education Law Act). According to art. 19 of the Act, the graduation of primary school enables students to educate in secondary schools. Graduating secondary school allows student to approach the secondary school-leaving exam and after passing, obtaining a certificate (the secondary school-leaving examination is not compulsory).

The technical school allows graduates not only to obtain a secondary school-leaving certificate after passing the exam but also obtaining a diploma confirming your professional qualifications after passing the examinations confirming the qualifications in a certain profession. Completing the first-degree industry school allows students to obtain a certificate confirming vocational qualifications after passing an exam confirming your qualifications in a given profession, as well as further education in a second-degree industry school in the profession, in which a common classification for the profession taught in the industry-level and second-cycle school has been separated. Graduates of first-degree industry school may also educate in secondary school for adults starting from year two. The second-level school industry gives the possibility to obtain a certificate confirming vocational qualifications in the profession taught at the technical level, in which the common qualifications for the profession taught in the industry school of first and second degree was separated, after passing the exam confirming the qualifications in a given profession and obtaining a certificate of secondary school-leaving exam.



Special training schools allow you to obtain a certificate confirming the preparation for work. Post-secondary schools enable obtaining a certificate confirming vocational qualifications after passing examinations confirming qualifications in a given profession (The Act of 14 December 2016. Prawo oświatowe). The person completing a 4-year general secondary school is about 18-19 years old, a graduate of technical secondary school, about 19-20 years old.

### **3. Characteristics of educational profiles on the example of selected secondary schools of the Opolskie Voivodeship**

Young people choosing to study in a 4-year secondary school, have to fulfil several conditions. One of them is good results from the exam at the end of a primary school. Secondary schools as well as technical ones have a limited number of places that is why there is a point threshold from which schools can recruit students to particular classes.

This type of school prepares young people, mainly for the school-leaving exam, so that graduates can get to certain studies after graduation. Therefore, each secondary school introduced specific profiles of education corresponding to the interests of young people, the needs of universities and the labour market. In principle, all secondary schools in their educational offer have classic educational profiles such as:

- mathematics
- biology-chemistry
- humanist
- language

These profiles had to be varied with new elements corresponding to the directions emerging in higher schools (universities and technical universities). Therefore, in secondary schools, classes with the following profiles have been created. In the case of mathematical classes, these are branches, e.g.

- mathematics-IT
- mathematics-physics
- polytechnic (mathematics-physics-IT)
- polytechnic-economics
- engineering (mathematics and IT)
- business (mathematics-geography)

Schools with classes in biological and chemistry profile introduced such branches as:

- nature
- biology-chemistry with psychological inclinations
- medical
- healthcare profession(doctor)
- medical and pharmaceutical

Classes with a humanistic profile are primarily:

- social-legal
- humanistic-language
- humanistic-legal
- legal
- university social and humanistic class
- managerial - social
- history-social
- psychological
- geopolitical

In case of language classes these are:

- language-geography
- language-business
- linguistic
- tourist (geography-language) (Based on the websites of selected secondary schools of the Opolskie Voivodeship).

In addition, secondary schools also have sports, military and other. The choice is vast depending on the students' interests and their decisions related to the further path of education.

The main difference between a general secondary school and other secondary schools is that such school does not prepare young people for the profession. "General secondary school is an example of secondary school, which from the very beginning of its history has promoted a model of general education, not related to profession preparation" (Madalińska-Michalak, 2013). Young people can participate in projects implemented by the school aimed at, for example, equalizing their educational opportunities on the labour market by participating in monthly professional internships (Rajchel, 2015) in selected institutions, workshops and occupational counselling classes. However, not everyone can participate in them, secondly, internships as such are not mandatory, and thirdly they are not carried out cyclically. For students graduating this type of school which does not give any qualifications, further studying at university or post-secondary schools becomes a necessity.

These young people acquired theoretical knowledge, but not practical. The situation worsens when young people do not take the school-leaving exam or fail it (there is a possibility of retake) and after graduation, without skills and qualifications they are looking for employment.

#### 4. Unemployed people in the Opolskie Voivodeship according to the level of education

On a national scale, the Opolskie Voivodeship is the smallest. On 31 December 2017, the number of residents amounted to 990069 people. Young people aged 15-19 are 45627 people (Ludność, ruch naturalny i migracje..., 2018).

At the end of July 2018, 22 152 people were registered in county labour offices. Compared to the end of June 2018, the number of unemployed increased by 41 people, or 0.2% (Informacja o sytuacji na rynku pracy...). Young people up to 25 years old constituted 2,489 and in comparison, to June 2018 it increased by 29 people (Informacja o sytuacji na rynku pracy...). Figure 2 presents the structure of the unemployed due to their education in the Opolskie Voivodeship. Status on the end of December 2017.

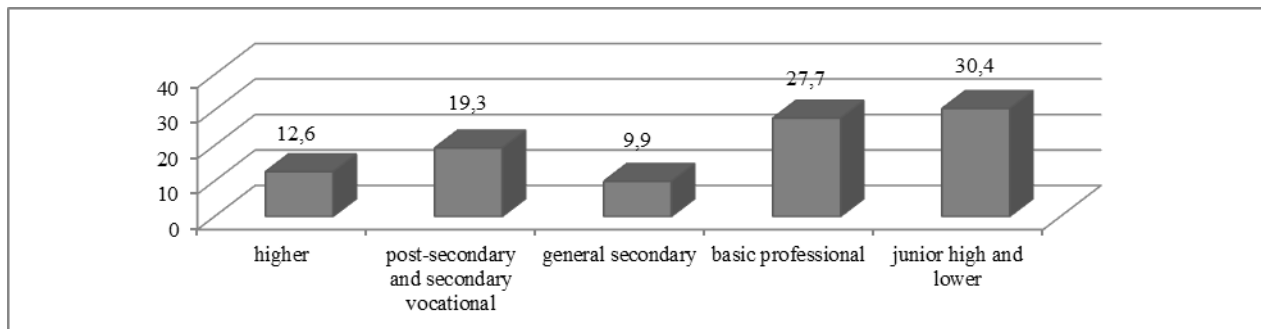


Figure 2. Structure of the unemployed due to education – status on the end of December 2017

Source: *Analiza sytuacji na rynku pracy województwa opolskiego w 2017 roku*, Wojewódzki Urząd Pracy w Opolu, pp. 20.

In the Opolskie Voivodeship at the end of 2017, the smallest number of unemployed had general secondary education (in statistical data it was not determined whether these persons obtained a secondary school-leaving certificate or graduated from school without a secondary school-leaving certificate). This situation may result from several reasons. Firstly, graduates of secondary schools do not have professional experience, therefore they can be taught to their profession. Secondly, young people of this type of school frequently take a holiday job. Thirdly, students also work as volunteers and thus, acquire skills (Raport z badania *Szkolne Kluby Wolontariatu*, 2016). Figure 3 presents the number of unemployed registered by the level of education.

The figures refer to the area of entire Poland.

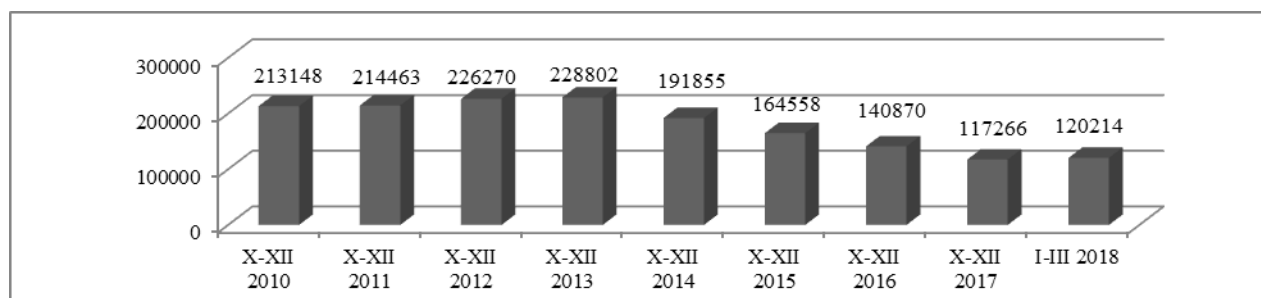


Figure 3. Number of unemployed in Poland according to the level of education

Source: *Bezrobotni zarejestrowani według czasu pozostawania bez pracy, wieku, poziomu wykształcenia*, [http://swaid.stat.gov.pl/RynekPracy\\_dashboards/Raporty\\_predefiniowane/RAP\\_DBD\\_RPRA\\_16.aspx](http://swaid.stat.gov.pl/RynekPracy_dashboards/Raporty_predefiniowane/RAP_DBD_RPRA_16.aspx)

Most unemployed people with general education were registered in the last quarter of 2013 (228802 people). This number was falling until the end of 2017. In the first quarter of 2018, compared to the last quarter of 2017, it increased by 2948 people. Young people do not always want to work at posts offered by County Labour Offices Since very often they do not correspond to their ambitions and interests. Table 1 presents selected job offers for people with general education reported to the County Labour Office in Opole. Status in August 19 and 20, 2018. Those interested could choose from 44 job offers.



Table 1. Selected job offers for people with general secondary education

Position	Required professional experience
Shop assistant Baby sitter	Lack of information Among others, experience in working with children in a nursery or kindergarten for a minimum of 2 years. Artistic and musical skills. A completed tutor course in a nursery or children's club.
Shop assistant – furniture department Office and administration employee	Ability to make contacts, experience in driving vehicles up to 3.5 tonnes Min. 2 years of experience in a similar position, availability, commitment, responsibility, practical knowledge of MS Office,
Office cleaner Secretary	Lack of information Experience in working in a similar position (secretary, reception), MS Office service, office equipment support, ability to work in a team
Coordinator of consultants for customer service	Minimum 3 months of experience in the customer service telephone industry, the ability to motivate employees supported by experience in managing a sales team
A specialist for logistics and office services	Computer skills, very good knowledge of English, willingness to work, knowledge of the construction industry,
Technical sales advisor	Experience in a similar position, min. 2 years, experience in driving a car, openness and ease in establishing contacts, good organization of work, ability to work in a team, knowledge of building and finishing materials
Warehouseman	Computer support, Office package, permissions to operate cranes, permission for a forklift driver
Fitness instructor	Conducting classes aerobics, pilates, yoga, healthy spine, permission to conduct fitness classes
HR, payroll and accounting clerk	Professional experience is welcome, knowledge of accounting and accounting rules (additional asset), very good work organization, independence, high communication and personal culture, willingness to learn.
Customer Advisor	Experience in a similar position is welcomed, communication skills, ease in acquiring knowledge, ability to conduct telephone conversations.
Blacksmith decorative products	Required 10 years of experience in a similar position, knowledge of Ukrainian in speech and writing, artistic skills, experience in forging artistic products, gas welding, TIG welding
The driver of the delivery truck	Category C driving license, 2 years of experience in a similar position, reliability, conscientiousness, ability to work in a team, knowledge of construction and finishing materials (additional asset)

Source: Job offers, County Labour Office in Opole, <http://pup.opole.pl/oferty> (19-20.08.2018).

When analysing job offers for people with general secondary education, several trends are easy to notice. First of all, people with basic or vocational education (e.g. cleaner) may be employed for some positions, and no secondary general education is necessary. Secondly, in job offers often the term "specialist" appears, assuming having specific knowledge, experience, special entitlements (e.g. permissions to run fitness classes, driving vehicles up to 3.5 tons, permissions to operate gantries etc.). Graduates of secondary schools after graduation are not specialists in any area and graduation of a profiled class does not mean the acquisition of certain rights desired by employers.

"Employers are (...) interested in both the quality of vocational education within the educational system as well as learning outcomes, that can guarantee a good adjustment of graduates to the needs - the most frequently mentioned in this context is the needs of the labour market" (Kozek, 2013).

Thirdly, experience in working in a similar position is generally required in all offers. Secondary school graduates are yet to get it. Fourthly, many job offers indicate the specific soft skills that an employee should have. "(...) soft skills belong to the so-called portable competencies that are indispensable for effective functioning in many diverse professional roles, and which, at the same time, greatly facilitate retraining, changing jobs and adapting to a new profession as well as new professional duties and tasks. Therefore, it is possible to combine the efficient functioning of the entity in the professional roles with the level of soft competences possessed" (Quote in: D. Fastnacht, 2006). The development of soft skills should take place at every lesson. A high school student who often has no professional experience should know what they are characterized by, how they can be developed and what role they play in the labour market. For a future employee, it can be an advantage when recruiting for a specific job.

## 5. Conclusion

Graduates of general secondary schools are specific employees on the labour market. Graduating the school does not give them any qualifications or eligibility. They do not have placement and most often professional experience. The school prepares them for the role of students, but not employees. A well-passed school-leaving exam allows them to take up studies in every subject and every university. The situation becomes problematic when a young person does not take the exam or does not pass it and therefore decides to look for a job. Job offers proposed by the County Labour

Offices in most cases do not take into account the fact that high school graduates, who have recently left the school walls, have never worked professionally. If they have already decided to take up a paid job, it usually did not give them specific rights or qualifications. The profile of the class they have completed does not mean acquisition of competences. It allows students to better understand what they can learn in a similar or related field, but at a higher education level. Where they can take up a job after graduation, what it will characterize with, what subjects should they choose at the school-leaving exam. These issues are introduced by teachers and school career counsellors. Graduates of secondary schools are, above all, theoreticians who can only increase their qualifications and gain professional experience. However, without employment opportunities, this is not possible. Employers, if they decide to accept a person with such education, most often require experience, specific skills and entitlements. Young graduates of secondary schools do not have these. Therefore, they undertake work on positions that can be performed by people with vocational and basic education or having no school-leaving certificate. Therefore, the lack of hard competences should be compensated by shaped soft competences. They are just as important as hard competencies, which a high school graduate can learn. Creativity, team work, the ability to resolve conflicts, willingness to learn and self-development, high personal culture - they most often appear in job offers and students can and must work on them. It is also important that young people do not give up their further education, even if they fail to pass the school-leaving exam at the time; they need to continue to study. "(...) there is a strong relationship between the level of education and the probability of unemployment. With the growing level of education, the probability of unemployment is clearly decreasing" (Polityka rynku pracy..., 2015).

The better education, the greater opportunities on the labour market, better earnings and opportunities to improve one's skills. Persons without work experience are in a very difficult situation on the labour market and often choose positions that do not correspond to their education. Graduates of a secondary school are good employees who can work in various professional disciplines but must be able to develop their skills and competences.

## References

- Analiza sytuacji na rynku pracy województwa opolskiego w 2017 roku*, Wojewódzki Urząd Pracy w Opolu, <https://wupopole.praca.gov.pl/documents/75476/899822/Analiza%202017/8e23fd20-4deb-4462-9680-2baa22aa7de3?t=1521638823315> (20.08.2018).
- Bezrobotni zarejestrowani według czasu pozostawania bez pracy, wieku, poziomu wykształcenia*, [http://swaid.stat.gov.pl/RynekPracy\\_dashboards/Raporty\\_predefiniowane/RAP\\_DBD\\_RPRA\\_16.aspx](http://swaid.stat.gov.pl/RynekPracy_dashboards/Raporty_predefiniowane/RAP_DBD_RPRA_16.aspx) (20.08.2018)
- Fastnacht D., *Miękkie kompetencje w zarządzaniu*, „Zeszyty Naukowe Wyższej Szkoły Zarządzania Ochroną Pracy w Katowicach”, Nr 1(2), pp. 109-114, (2006), <http://yadda.icm.edu.pl/baztech/element/bwmeta1.element.baztech-article-BUS6-0031-0043> (14.08.2018).
- Informacja o sytuacji na rynku pracy wg stanu na dzień 31 lipca 2018 roku*, Wojewódzki Urząd Pracy w Opolu, p. 1, [http://wupopole.praca.gov.pl/rynek-pracy/statystyki-i-analizy/?p\\_p\\_id=webcontenttabbedpublisherportlet\\_WAR\\_webcontenttabbedpublisherportlet\\_INSTANCE\\_LfMHA8a0gskZ&p\\_p\\_lifecycle=0&p\\_p\\_state=normal&p\\_p\\_mode=view&p\\_p\\_col\\_id=column-1&p\\_p\\_col\\_pos=4&p\\_p\\_col\\_count=5&\\_webcontenttabbedpublisherportlet\\_WAR\\_webcontenttabbedpublisherportlet\\_INSTANCE\\_LfMHA8a0gskZ\\_tab=0](http://wupopole.praca.gov.pl/rynek-pracy/statystyki-i-analizy/?p_p_id=webcontenttabbedpublisherportlet_WAR_webcontenttabbedpublisherportlet_INSTANCE_LfMHA8a0gskZ&p_p_lifecycle=0&p_p_state=normal&p_p_mode=view&p_p_col_id=column-1&p_p_col_pos=4&p_p_col_count=5&_webcontenttabbedpublisherportlet_WAR_webcontenttabbedpublisherportlet_INSTANCE_LfMHA8a0gskZ_tab=0) (20.08.2018).
- Kozek W., *Rynek pracy. Perspektywa instytucjonalna*, Wydawnictwa Uniwersytetu Warszawskiego, Warszawa, (2013).
- Liczba absolwentów kończących szkołę ponadgimnazjalną według poziomu wykształcenia*, [http://www.absolwenci.poznan.pl/raporty/liczba\\_absolwentow\\_konczacych\\_szkoly.html](http://www.absolwenci.poznan.pl/raporty/liczba_absolwentow_konczacych_szkoly.html) (20.08.2018).
- Ludność, ruch naturalny i migracje w województwie opolskim w 2017 r. Population, vital statistics and migration in opolskie voivodship in 2017*, Urząd Statystyczny w Opolu. Statistical Office in Opole, Opole 2018, Tablica 3. Ważniejsze dane o stanie, ruchu naturalnym i migracjach ludności; Tablica 8. Ludność według płci i wieku w 2017 r. stan w dniu 31 XII, <http://opole.stat.gov.pl/publikacje-i-foldery/ludnosc/ludnosc-ruch-naturalny-i-migracje-w-wojewodztwie-opolskim-w-2017-r-2,14.html> (20.08.2018).
- Madalińska-Michalak J., *Oferta edukacyjna i jakość kształcenia w publicznych liceach ogólnokształcących w Łodzi*, Wydawnictwo Uniwersytetu Łódzkiego, Łódź, (2013).
- Nowa struktura szkolnictwa w Polsce*, <https://www.nowaera.pl/strona-glowna/reforma-oswiaty-pod-lupa/nowy-ustroj-szkolny> (14.08.2018).
- Job offers, County Labour Office in Opole, <http://pup.opole.pl/oferty> (19-20.08.2018).
- Polityka rynku pracy. Teoria i praktyka*. Red. nauk. M. Frączek, Polskie Wydawnictwo Ekonomiczne S. A., Warszawa, (2015).
- Rajchel A., *Zdolność do przyszłego zatrudnienia absolwentów liceów ogólnokształcących na przykładzie projektu „Staże zawodowe dla uczniów liceów ogólnokształcących Miasta Opola* [w:] *Wyzwania rynku edukacyjnego wobec rynku pracy- wymiary lokalne, regionalne i ponadregionalne*, red. nauk. B. Wiśniewska-Paź, Wydawnictwo Uniwersytetu Wrocławskiego, pp. 169-184, Wrocław, (2015).
- Raport z badania „Szkolne Kluby Wolontariatu”*, Ministerstwo Edukacji Narodowej, Katowice, listopad 2016, pp. 3-22, [http://www.slaskie-wolontariat.org.pl/wp-content/uploads/2017/01/raport\\_rcw\\_mlodzi2016.pdf](http://www.slaskie-wolontariat.org.pl/wp-content/uploads/2017/01/raport_rcw_mlodzi2016.pdf) (20.08.2018).
- Regulation of the Minister of National Education of March 13, 2017 *w sprawie klasyfikacji zawodów szkolnictwa zawodowego* Dz.U. 2017 item 622 as amended
- The Act of 14 December 2016. *Prawo oświatowe*, Dz.U. 2017 item 59 as amended

## The Analysis of the content of newspapers: „Cronica Văii Jiului”, „Gazeta de Dimineață” and „Ziarul Văii Jiului”

Cosmin Sergiu Cremene

*Vasile Alecsandri, nr.1B, Bl3C, Ap.25, Vulcan, jud.Hunedoara, Romania*

---

### Abstract

In order to create a clearer vision, more profound about the particularities of evolution or regression of written press, I have resorted to an analysis of it for a period of three years, namely 2011, 2012 respectively 2013. The newspapers on which the analysis was made were "Cronica Văii Jiului", "Gazeta de Dimineață" and "Ziarul Văii Jiului", the latter being the only publication that did not give me the papers for analysis.

The analysis of this three newspapers: "Cronica Văii Jiului", "Gazeta de Dimineață" and "Ziarul Văii Jiului" have been transposed in four dimensions namely: The demographic and social dimension, The economic dimension, The political dimension and The cultural dimension.

This analysis will show whether the press in Jiu Valley is ready to evolve from a media point of view.

Processing of newspapers was made with the help of programs such as soft-wear (QuarkXpress Version 8.2, A-PDF Merger, MaxQda 12).

---

### 1. Introduction

The written press often contributes to changing the importance of figures in order to give a certain perspective to a fact presented in the sociological report, depending on the specifics of the publication, or/and political partisanship (where appropriate). Simplifying, it is desired to manipulate the behavior of individuals in the sense of particular interest group that considers that a certain type of report that is presented to the general public will generate a favorable reaction on the part of it.

### 2. The demographic and social dimension

"The second component of demographic growth is international migration [...] Immigrations have the same meaning with births, emigrations represent losses..." Vladimir Trebici

A clear definition of "demography" is given by Vladimir Trebici in his demography (1979): "Demography is the social science that studies the human populations spatially delimited and burdened by social significance, their size and spatial distribution, their structure according to their demographic and socio-economic characteristics, their evolution, the direct factors that determine the evolution of the population - fertility, mortality, migration socio-economic factors that influence demographic phenomena in order to highlight the regularities they produce." This dimension, which is very important for the entire community studied as well as for society as a whole, has a decisive role in the daily existence of each of us.

Following the revision of the electoral lists of Vulcan Municipality on 21.10.2013, the population was 22,505 people. As we can observe, there is a discrepancy between the number registered by the County Directorate in 2011 (fig.1) and that found by the NIS (table no.1) of 27,998 people, the reason being one that can attract funds in this municipality (reporting a larger number than in reality).

"Lowering of the population poses a real threat to the sustainable development of the long-term, especially in conditions of ageing of the population, imposing measures is the creation of new jobs and to attract and maintain young people in the city ". (Development Plan of the Jiu Valley 2014-2020, p. 215).

For a clearer view of the evolution of the main demographic indicators registered at the level of Vulcan municipality during the period 2008 - 2012 is presented in table 1.

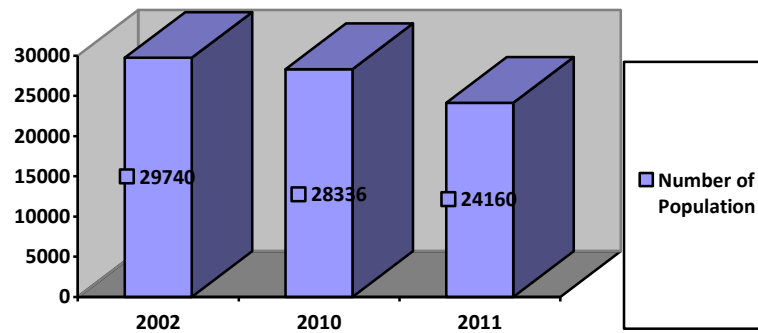


Fig.1 The population is stable in 2002, 2010 2011 respectively (source: Direction of statistics, Hunedoara County)

Table 1 The main demographic indicators registered at the level of Vulcan municipality during 2008 - 2012

Population	2008	2009	2010	2011	2012
Stable population - total on 1 July	28713	28413	28336	27998	27678
Stable population - women on 1 July	14513	14394	14372	14225	14065
Live births	229	280	244	215	206
Deceased - total	261	259	254	258	237
Deceased under one year	3	4	2	3	2
Marriages	179	191	132	114	127
Divorces	91	83	92	87	85
Establishments with domicile (including foreign migration )	301	300	452	-	-
Departures with domicile (including foreign migration)	589	441	664	-	-
Settlements of residence in the locality on 1 January	221	217	159	152	118
Departures from the locality on 1 January	342	415	363	291	310
Emigrants	4	4	4	-	-
Immigrants	3	1	3	-	-

### 3. The economic dimension

Senator PSD of the Jiu Valley, Nicula, appeals to politicians who have contributed to the politicians who have contributed to burial in the Jiu Valley mining to take over their work results and says that CNH was not devastated by the miners or their direct bosses keep on surprising him that those Ministers of Economy does not come out with statements in explaining how many moves were made in the Jiu Valley via CNH for cost price of coal that should be at the level of the one practiced in the EU declares Cosmin Nicula for the "Cronica Văii Jiului" in art. „Cosmin Nicula: The National Company of Black Coal is the mirror of the political incompetence of those who led the Ministry of Economy” - 5.10.2012.

An important article that awakens us from the state of lethargy is given in the daily Jiu Valley Chronicle where the researcher Dr. Eng. Valeriu Pleșea concerned about global energy issues, was kind and gave an exclusive interview in which he stated that 'Germany aims to give up nuclear power in favor of thermal power stations on coal. The crisis decides what attitude to take and being cheap... In these conditions and we need to do something because there is a fierce 'competition' for survival, and we have to be competitive, otherwise coal will be brought out. They keep their eyes on us...' (Valeriu Pleșea, 2013). The article specifies that 'in the year 2012, energy coal had the highest growth in the world. And to not buy this coal from countries that are not under sanction environmental protocols-such as the US and China, countries that have coal production manner that could bury a country like Romania: 997 million tonnes and 3,100 million- Canada has upset and announced its withdrawal from the Kyoto Protocol, a protocol that has no effect (instead of lowering emissions due to the measures imposed on accession countries, these noxes have increased) but it eats the money and kills them the economy...' (Cronica Văii Jiului, 2013)

Tourism what seemed to be an alternative to the Jiu Valley mining proved to be a real failure indicates Luiza Andronache (2013) in art. 'The Jiu Valley, without mining, without tourism, without the future' reports that the Project envisaged the union of the resorts Pasul Vâlcău with Straja stepping on the spot, the development of the resort at Vulcan as Petrita, construction of the resort Dobroia is in the same phase for several years, to walk the papers and ask for approvals from the ministries invoking that there is no money to continue the work.

References should be added at the end of the paper, and its corresponding citation will be added in the order of their appearance in the text. Authors should ensure that every reference in the text appears in the list of references and vice versa. Indicate references by Clark et al., 1962 or Deal and Grove, 2009 or Fachinger, 2006 in the text. The actual authors can be referred to, but the reference citation(s) must always be given.

Some examples of how your references should be listed are given at the end of this template in the 'References' section, which will allow you to assemble your reference list according to the correct format and font size.

#### 4. The political dimension

Vulcan Municipality has dressed up many 'political clothes' that have not given a good image to this city, such as the conservative party, the democratic party, and maybe this year it will wear 'the coat' of the national liberal party.

We observe a strange phenomenon in all three daily newspapers following their transformation and processing for 2011, namely that the „Cronica Văii Jiului” is presented to us only in November and December; Gazeta de dimineață also two months of October and December respectively and in Ziarul Văii Jiului the first months of the year, January and March. (fig. 2)

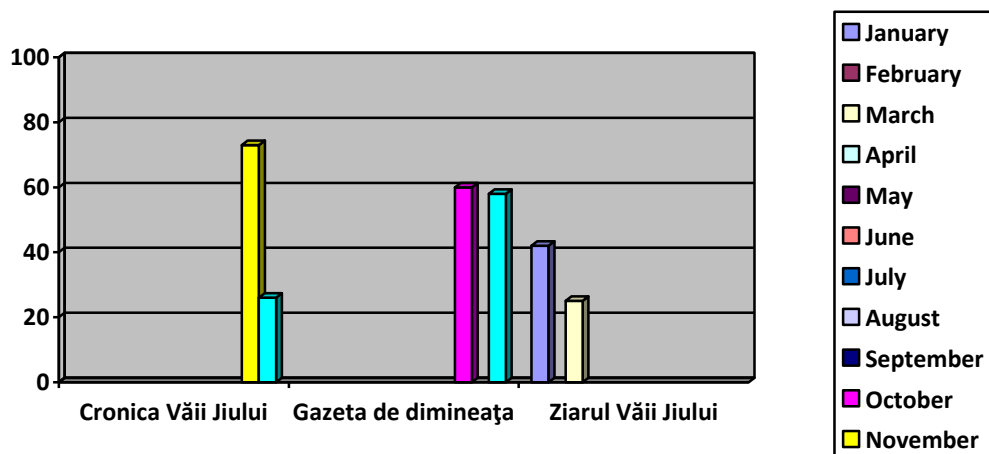


Fig. 2. The absolute frequency of the PNL party in the three newspapers analyzed for 2011

As we can see in the figure below (fig.3), the national liberal party has the most appearances, which are given by several articles circulated around the local council of Vulcan, namely 'PSD Councilors, PNL and PRM in Vulcan boycott the activity of all Mayors of the Jiu Valley' (Marius Mitrache, Gabriela Rizea, 2012); 'PNL and PSD Vulcan divorce from Dorel Șchiopu' (Anamaria Nedelcoff, 2012); 'Șchiopu tricked by' fox' (Diana Mitrache, 2012).

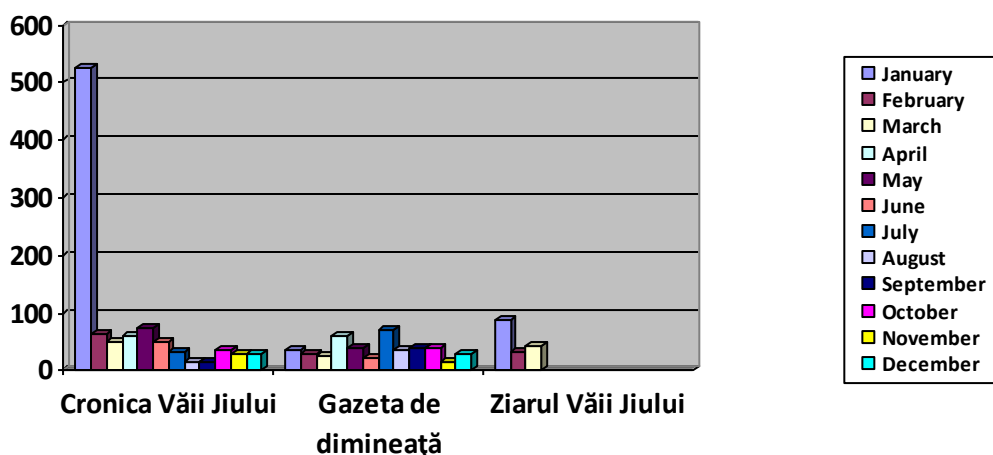


Fig. 3. The absolute frequency of the PNL party in the three daily newspapers analyzed for 2012

Making a comparison between the three daily newspapers on the emergence of the liberal national party in these, we noticed a more intense promotion of the party from the Cronici Văii Jiului which, as can be seen in (fig.4), October 120; April 107 times and 98 times in June 2013.

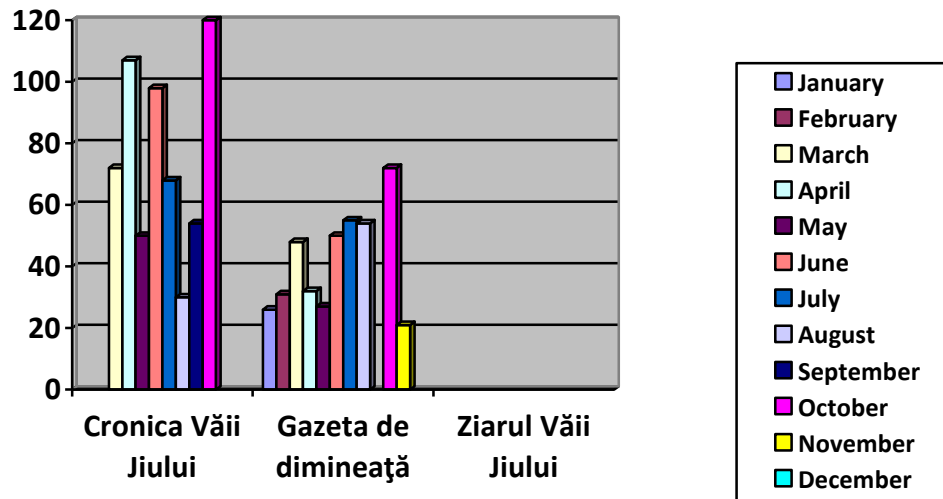


Fig. 4. The absolute frequency of the PNL party in the three daily newspapers analyzed for 2013

As I said, the Ziarul Văii Jiului was the only one who did not provide me with the papers for analysis, invoking different pretexts that do not have databases that are formed and cannot be transferred. Finally, a person whose name I do not want to disclose gave me the personal stick the so-called 'newspapers in pdf format.' Which turned out to be in another format and put several extensions to mask their presence on stick. Transforming Quark format files into pdf. and lipid them with the 'A-PDF Merge' program resulted in 13 newspapers (January) and 8 newspapers (March) of 2011.

Although I only had two months of daily newspaper 'Ziarul Văii Jiului', I wanted to see the frequency of the PNL and PSD appearing in it. We have seen a greater rise from the Social Democratic Party, which leads to the conclusion that this daily could be under the 'wing' of the PSD. (fig.5)

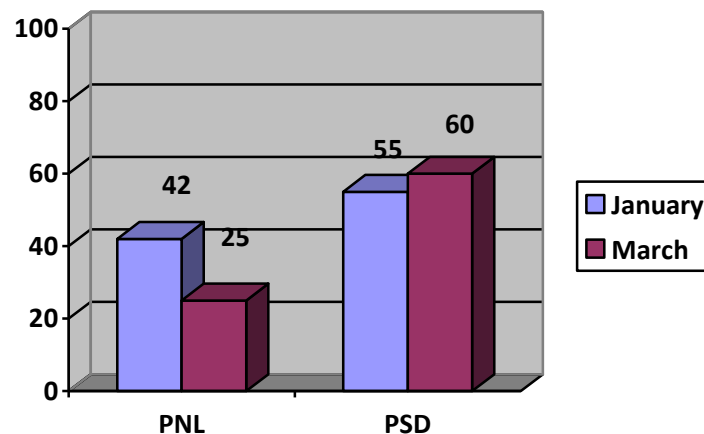


Fig. 5. The absolute frequency of the PNL party in the three daily newspapers analyzed for 2013

## 5. The cultural dimension

In Achim Miha's view (2002), culture is the way of life of a group of people in the circumstances of a particular environment created by man and made up of material and non-material products transmitted from generation to generation.

Currently trying to rediscover and, although we are witnessing an ageing of the population and the decrease in young people.

Along the years, have formed numerous bands (vocal-instrumental groups) such as „Color” Group , „Stacatto” Group, „Astral” Group, Folklore Group „Doruleț” respectively „Flori de munte” that brought numerous awards and have given evidence that they know to keep alive the tradition of folk that were in various festivals in the country and abroad.

Few people know that in the JIU Valley School No. 2 in Uricani, a classroom was converted into a Museum, about the people and customs of the area. The idea belongs to a family of teachers, Petre and Violeta Udrea. Their passion for history and for the ancestral habits have made to gather data and objects that reflect past people in the JIU Valley. The Museum's story began in 1978, when Petre Udrea, then a teacher at the school at the Children's House in Uricani, he received the task to do a project about the history and customs of the JIU Valley. Since there was a database about the population in the area and had no real data about people, customs and history of the place, Petre Udrea He began to collect objects, documents, photographs, clothing, paintings and icons. (Anamaria Nedelcoff, 2011).

Considering the fact that in the 'Jiu Valley Chronicle' only two months were analyzed, namely November and December of 2011, the number of customs and traditions was limited. A feast was connected to the night 'Saint Andrew called in the folk tradition of the 'night of the undead (strigoi)' - the evil spirits that fill the earth and are stronger than the rest of the year. In Romanian mythology, the undead (strigoi) are the souls of the dead who are supposed to go out of the tomb night and take a ghost or animal form to cause trouble. In the village, as a rule, it is said of evil people, greedy, with a 'small and black' soul, that they will become (or have become) undecided (strigoi) after death. On the night preceding the celebration of Saint Andrew (November 29/30), especially in the countryside, strange rituals are practiced, believing that it is easier to find protection from all evils, well-being and even love. Most rituals are devoted to attracting love. By hiding under the pillow of a holy basil, it is believed that the image of the 'future husband' is dreamed up. Another method used to know the future is to look at midnight, between two fires, in a glass of untouched water, placed on ashes. In the center of the glass there is a wedding ring that has already been sanctified by the priest by the religious wedding, and it is believed that in the wedding ring the face of the 'future husband' appears, if it is intensely watched for a few minutes. All the night of St. Andrei are practiced and popular weather predictions for the coming year. Usually in the attic of his house are loaded on 12 healthy onions as big, that are left there until the Christmas evenings, when it is the result. Each onion is assigned the name of a month. Crows that ruined indicate rainy months or hail, and those that sprouted - months favorable to harvest. ' (Marius Mitrache, 2011).

According to Ion Ghinoiu, the author of the volume Days and Myths. The Romanian peasant's calendar, Nativity's legends invite us to the ethnographic landscape of a pastoral village, where Santa Claus and Santa Claus lived, with large houses and many stables. Suddenly an unknown woman appears in their lives who, feeling the time to give birth, asks for help. If the first one denies it, the second one stretches out a hand. But not knowing that the woman is the Mother of God, she does not receive her in the house and sends her to the cattle's stable. Santa's wife helps to give birth, without her husband's knowledge, but is then punished by cutting her elbows. When Christmas finds out that Jesus was born in his stable, he repents and asks for forgiveness to God, becoming 'the first Christian,' the 'oldest saint,' 'the husband of the woman who mourned Mary. It is said that he was so excited that the day he shared his whole fortune with the poor children, from where the tradition of making Christmas gifts, especially to the children. (23.12.2011 'A Happy Christmas!' - Chronicle Jiu Valley)

The written legend (volume 'Romanian Mythology' by M. Olinescu, p. 182, 'The Worstest') tells us that the mourners are three in number, three maids from the time of Emperor Alexander Macedon. On his journeys, he came to a spring of living water and filled a pot with the elixir of immortality. The three maids stole the living water, drank it, and became immortal. God decided then that they establish the course of life of every man on earth from then on. The legend tells us that they lived in a beautiful palace, where they burn as many candles as there are souls on the earth. From time to time to time turns off one light but it appears another instead, when a child is born. One of the mourners pours oil into the candle, and it will burn as long as he has his child to live.

Interesting is the ritual performed by the mockery. They go three times in the night at the house where a child was born, either a girl or a boy, to bruise them. The first of these, called the Mug, holds the fork and the throat and sets down to the smallest detail what is going to happen. The second is called Fate, it carries the quark (a bundle of wool in hemp or borangic) to life, and the third, most feared, is Death that has the power to curtail the thread of life. The third, most urgent, with the greatest power, dresses each other with other servants. If one day wears price clothes, all those born on that day will have wealth and happiness. On other days he's dressed in a merchant's or peasant's clothes, those who are born that day will earn their daily living hard. The brightest fate is those born on the day the bridegroom dresses in rags. They will not have much joy in life.

In order to attract the mercifulness of the mockers, the momarlans bring offerings whenever they have the occasion, but especially on the day of the great feasts (Pascal, Christmas, Saint Peter and Paul, St. Elias, etc.). This ritual was gathered from the omer of Tirici - Cimpa, Gărgan Ion (Ionică), at the wonderful sheepwalk of Poiana Muierii (or of the bride) led by the Tirici village shepherd Petrică Tiric. (Petru Bolog, 2013)

## References

- Achim Mihiu, *General Sociology*, Publishing House Napoca Star, Cluj-Napoca, (2002).
- Anamaria Nedelcoff, *Ancestor Message - Arc Over Time*, Cronica Văii Jiului, 7.12.2011.
- Anamaria Nedelcoff, *PNL and PSD Vulcan are divorced by Dorel Şchiopu*, Cronica Văii Jiului, 24.01.2012.
- Cosmin Nicula, art. *Cosmin Nicula The National Company of Huile is the mirror of the political incompetence of those who lead the Ministry of Economy*, Cronica Văii Jiului, 5.10.2012.
- Diana Mitache, *'Shiopo fooled by' fox*, Cronica Văii Jiului, 30.01.2012.
- Marcel Olinescu, *Romanian Mythology - With author drawings and xylograms*, Publishing House SAECULUM VIZUAL, Bucharest, 2004.
- Marcel Olinescu, *"A Happy Christmas!" - Jiu Valley Chronicle - The written legend (volume "Romanian mythology")*, 23.12.2011, pag.182
- Marius Mitache, *Wolf's Night*, Cronica Văii Jiului; 28.11.2011.
- Marius Mitache, Gabriela Rizea, *'The PSD, PNL and PRM councilors in Vulcan boycott the activity of all mayors in the Jiu Valley'*, Cronica Văii Jiului, 20.01.2012.
- Petru Bolog, *' Customs and traditions-MOMÂRLANII and URSITOARLE the COURSE of LIFE-what you written in your forehead is! '*, Cronica Văii Jiului, 25.03.2013.
- Valeriu Pleşea, art. *'EU uses' torture tools 'for Romania While mines were shut down in the Jiu Valley, coal production has grown sharply in Europe and around the world'*, Cronica Văii Jiului, 12.03.2013.
- Vladimir Trebici, *Information system of demography*, *Demography*, Scientific and Encyclopedic Publishing House, Bucharest, (1979).
- Development Strategy of Vulcan Municipality 2014 - 2020* (updated 2015).



## Residents' perception of the studied communities through a direct survey

Cosmin Sergiu Cremene \*

*Vasile Alecsandri, nr.1B, Bl3C, Ap.25, Vulcan,336200, jud.Hunedoara, Romania*

---

### Abstract

The direct survey was conducted on the basis of a questionnaire containing 45 items, in which they caught the types of questions starting with the opinions, factual, dihotomic as well as some questions taken from the Public Opinion Barometer in May 2006. The questionnaire was completed by the respondents, at their home, in the presence of the field operator.

The period of data collection (field phase) was March - April 2015.

This research was carried out in the municipality of Vulcan having as target population a number of 336 random people taken from different social backgrounds such as: Vulcan Town Hall, churches, schools, etc. of the total population of the Vulcan municipality of 22,505 people, their number was found in the following revisions of voter lists in 21.10.2013 by me at City Hall.

*Keywords:* written press, journalist; comunity, media;

---

### 1. Introduction

Direct surveys collect information about events, facts, happenings where the subjects are involved, and do not ask themselves about intimate facts. While the indirect ones require information about facts, events to which the subjects either participated or did not participate to protect the subject, they are asked to appreciate the behavior and attitudes of other people involved.

Both the definition of problems and the perception of their severity, urgency, and priorities differ from one social category to another. While young people are preoccupied with finding a job, retirees are concerned about the issue of medicines. Therefore, different social segments will propose different themes and priorities on the public agenda. Social issues differ depending on the type of community, region, county, city, neighborhood. The needs of the population in a commune differ significantly from those of the population in a mono-industrial city, as well as those of the inhabitants of major cities. The needs of the population in a floodplain area will be different from those of the inhabitants of a drought.

Bianca Radu (2015, pag.24), Specifies that Tonnies and Weber have identified four essential aspects of communities: (a) the interdependence between people; (b) a high degree of uniformity in relation to certain measures and norms shared in the community; (c) their presence more as highly internalized elements than as formally expressed elements; (d), and as such, as a whole of a common culture and way of life, the existence of a strong sentiment of engrossing with an outgroup (Amerio, 2003, pag. 32)

"The survey-in general-is one of the oldest, but also the complex methods (techniques) for investigation. This is supposed to lead to the clarifications needed, at a broad consensus on the content, features, advantages and its limitations. However - or perhaps precisely because of this - there are still many controversies and uncertainties, ambiguous appreciations and disputable meanings '. (Septimius Krausz, Irinel Stegar, 2007, pag. 121)

---

\* Dr. Cremene Cosmin Sergiu. Tel.: 0799835324  
E-mail address: c.sergiu@yahoo.com

## 2. Community issues

Given the rather precarious situation of the entire Valley, the municipality of Vulcan was one of the few where public administration involvement in road infrastructure development was seen, although citizens' problems are quite different, namely: more than a quarter are afraid of health, a quarter of the future of children, 23.2% of prices, less than a quarter of the fact that they finish a school and remain unemployed, 5.4% others and 1.4% fear a possible strike. (fig.1)

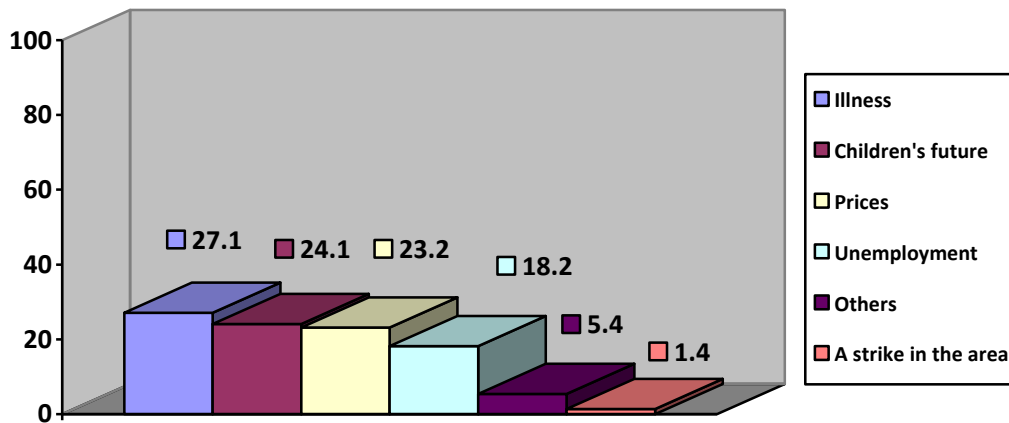


Fig.1 Things that induce a state of fear

Following the correlation between occupation and fears, we found that less than half of the household (40%) and those employed (33.3%) are afraid of a possible illness; 34.1% of pupils and students are afraid of their future (34.1%), while the unemployed have fears about prices and unemployment - 31.6% each (perhaps the fear of remaining unemployed) and, as far as pensioners are concerned, their fear is given by prices as well as an eventual 29% disease each of them. (fig..2)

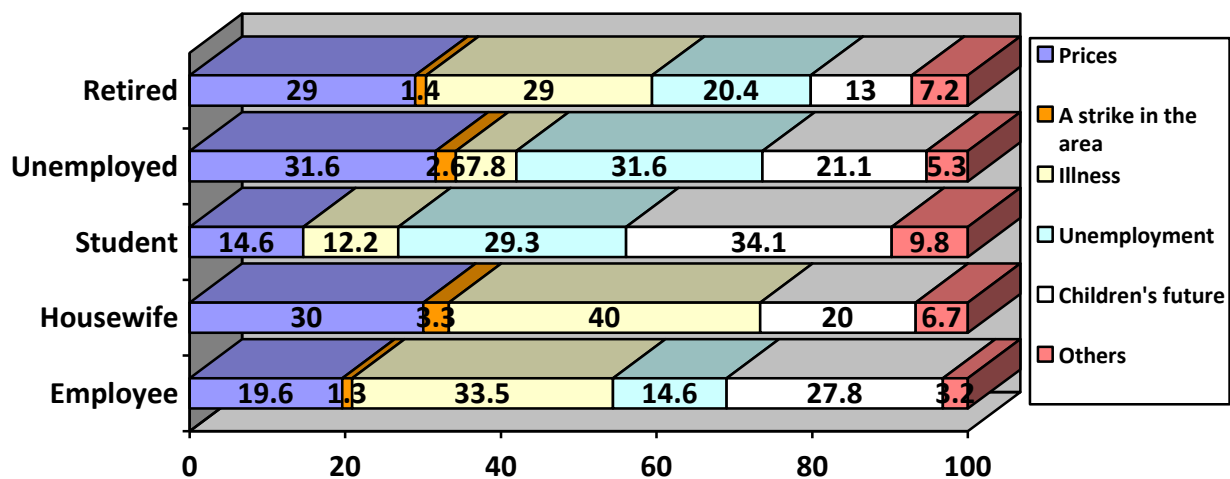


Fig. 2. The correlation between occupation and fears

Almost a quarter of those surveyed believe that the social reality and problems in the Jiu Valley are scattered by political parties through the press. (table 1)

Table 1. Covering social reality and issues by political parties through the press

	Yes, In what way?	No	I do not know	Total
Frequency	74	77	185	336
%	22	22,9	55,1	100

And the means used by them are multiple starting with 46%-by bribery; 20.2 percent through blackmail; 9.5% through promises; 8.1%-political interests; 6.8% against favors favors; 4%-affinities; 2.7 through concealment and lack of professionalism of journalists. (table 2)

Table 2. The means used by political parties to present another social reality and the real problems of the Jiu Valley

	Frequency	%
Bribery	34	46
Blackmail	15	20,2
promises	7	9,5
Political interests	6	8,1
Favors v. favors	5	6,8
Affinities	3	4
Concealment	2	2,7
The lack of professionalism of journalists	2	2,7
Total	74	100

The opinions of the interviewed persons about the period before the revolution and the current one from the administrative, demographic, economic, legislative, political and social point of view have many opinions, namely that from an administrative point of view one can notice an improvement of the system; demographically, we can see that the balance tends towards a negative natural increase, an aging population and declining birth rates; the economy is the only one in which almost half of the respondents say that this sector has turned around; at the intersection between good and evil; in terms of the political sector, we are dealing with a homogeneity of the direction in which this sector evolved, and in the latter there is a dissatisfaction on the part of the respondents in the social sector. (fig. 3)

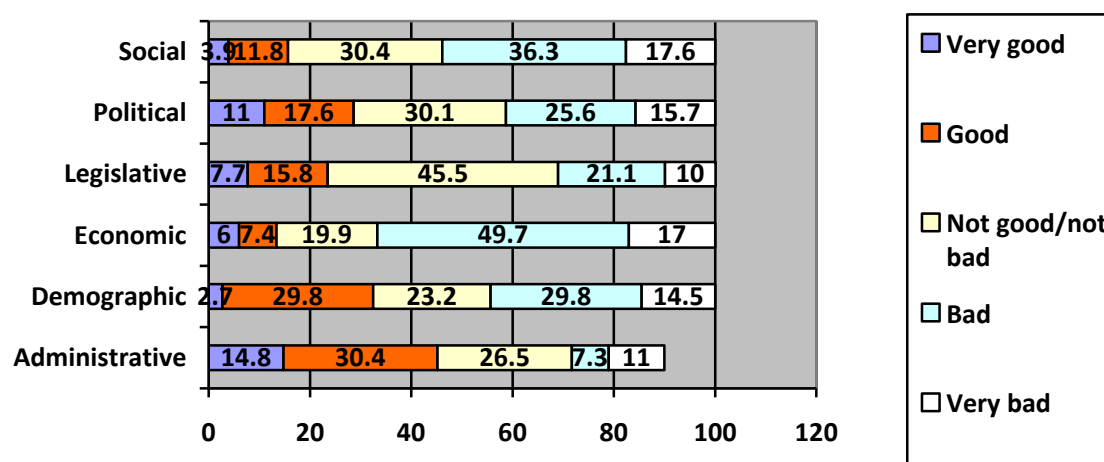


Fig. 3. Evolution of the Jiu Valley from an administrative, demographic, economic, legislative, political and social point of view

To see what age group and education level who have expressed their opinion on the degree of evolution have turned to relations between age, studies and developments in terms of administrative, demographic, economic, legal, political, respectively social as follows in the description below:

From the administrative point of view, people with mid-level (professional - 70.6%, post-secondary - 60%) respectively those with 54.1% higher education aged 18-44, said that this sector evolved for the better while those aged 65 years and over with gymnasium studies - 52.4%; professional - 50%; 80% of all high school graduates and all those without a study said that this sector has reversed.

From a demographic point of view, most of those with high school education and aged 65 years and over said that this sector has neither evolved nor deviated; nearly half of those aged 45-64 and middle school say that it has invaded; half (53.8%) of those aged 18-44 and gymnasiums are more positive saying that this sector is heading for the better.

Realizing the correlation between age, education and evolution of Jiu Valley from economic point of view, we note that all categories of age: between 18-44 years of age, between 45-64 years, 65 and over have stated that this sector decays a day when the reason is quite obvious when looking at the mining sector, it is the one that still supports the economic sector.

Most people aged 65 and over who have professional studies say that from a legislative point of view, Jiu Valley is at the intersection of evolution and regression. The same can be said when it comes to the political one for more than half of those with post-secondary studies and 18-44 years of age respectively for the majority of those aged 65 and over.

With regard to the social sector, for the majority of categories of age and with an average level of study have a neutral position toward the negative.

### 3. The interest manifested against mass media

More than a quarter of those questioned show interest in buying a newspaper several times a week. (table 3)

Table 3. Periodicity of buying a newspaper

	Daily	Several times a week	Several times a month	More rarely	Never	I do not answer	Total
Frequency	51	84	77	77	23	24	336
%	15,3	25	22,9	22,9	6,8	7,1	100

The vast majority of those interviewed stated that there are more points of sale of newspapers and magazines in the municipality. (fig. 4).

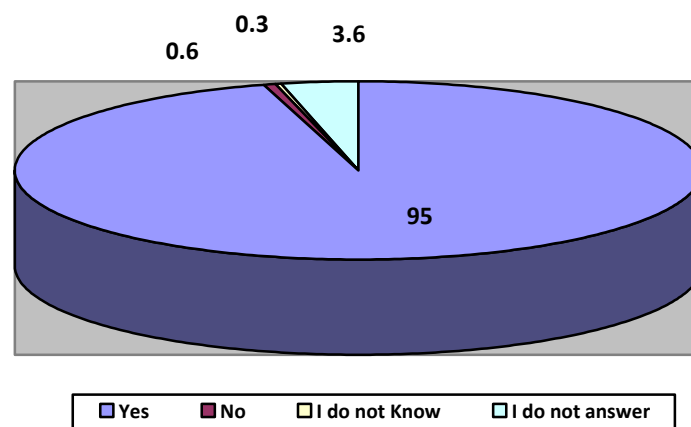


Fig. 4. The existence of points of purchase of newspapers

One-third of those questioned believe that the press should belong to both the State and the private environment; a quarter say they have to go into the state's attributions; less than a quarter are private and 22.3% abstain. (table 4)

Table 4. Media coverage

	State	Private	To exist and State and private	Don't know/no answer	Total
Frequency	79	59	123	75	336
%	23,5	17,6	36,6	22,3	100

A quarter of those who said they knew about the existence of the Romanian Press Club. (table 5)

Table 5. Media coverage

	Yes, go to question 30	No, go to question 31	Do not respond	Total
Frequency	90	123	123	336
%	26,8	36,6	36,6	100

And more than half of those who have expressed their opinion about CRP say they does anybody know; I do not know; do not answer, and less than a quarter have a good opinion and 8.8% have a bad opinion about its activity (table 6).

Table 6. The opinion on the activity of the Romanian Press Club

	Rather good	Rather bad	Does anybody know	do not know	Do not respond	Total
Frequency	12	8	20	13	37	90
%	13,3	8,8	22,3	14,4	41,2	100

I can say at the end of this article that after one year of my PhD thesis as stated therein and that the press is "dying", it has been confirmed that at present there is no longer any point of sale of newspapers.

A small part of today's journalists more respects the right to privacy and private life, as there is a continuous scurry after the show, we look at the television channels that are more interesting, more attractive, more spicy, one describes and brings before us as a private, intimate life. When they collide with each other what do they do? They penetrate one into the life of the other and brings out all the 'misery' everything, because he thinks this way it becomes interesting and it can 'knock down' the potential opponent, that is the world we live in.

Less than half of the subjects consider that a large number of journalists still show professionalism in this profession. (table 7)

Table 7. Professionalism on the part of journalists

	Almost all	A large part	A small part	Almost none	I do not know	Total
Frequency	62	138	87	33	16	336
%	18,5	41,1	25,8	9,8	4,8	100

Nearly half of respondents say that almost all journalists are influenced by their chiefs to pass on information. (table 8)

Table 8. Influence of journalists by the bosses when a news story

	Almost all	A large part	A small part	Almost none	I do not know	Total
Frequency	159	102	43	11	21	336
%	47,3	30,4	12,7	3,3	6,3	100

Of those questioned mentioned the fact that a large proportion of journalists give exaggerated importance with regard to the topics, which may be due to the fact that they gather many people in front of the tv (table 9).

Table 9. Exaggerated importance to some topics uninteresting

	Almost all	A large part	A small part	Almost none	I do not know	Total
Frequency	68	192	51	19	6	336
%	20,2	57,1	15,2	5,7	1,8	100

Nearly one-third of subjects considered that journalists are both presenting some topics that are not in the public interest and against them (table 10).

Table 10. Presenting some topics that are not in the public interest on the part of journalists

	Almost all	A large part	A small part	Almost none	I do not know	Total
Frequency	76	105	108	32	15	336
%	22,6	31,3	32,1	9,5	4,5	100

## References

- Bianca Radu, *Resilience of former mining communities*, Cluj University Press, Cluj-Napoca, (2015).  
 Piero Amerio, *The evolution of the concept of community in Western culture in the Handbook of community psychology*, coord. Zani Bruna, Palmonari Augusto, Publishing House Polirom, Iași, (2003).  
 Septimiu Krausz, Irinel Stegar, *Methodology and Methodic of Sociology*, Publishing House Matrix Rom, Bucharest, (2007).

# The organizational culture in junior High Schools in the Druze Sector

Nabila Kheir Faddul<sup>a\*</sup>, Nicolae Aurelian Bibu<sup>a</sup>, Doina Dănăiață<sup>a</sup>

<sup>a</sup>West University of Timisoara, Romania

---

## Abstract

The present study examined the dominant organizational culture in the Druze schools in the High Galilee in Northern Israel. It examined the current organizational culture and the preferred organizational culture. The Organizational Culture Assessment Instrument (OCAI) developed by Cameron and Quinn (1999, 2006, and 2011) was used for the purpose of this study. 220 staff members from nine schools including principals, teachers, and workers were chosen as research samples. Research findings showed that the clan culture is the current dominant culture and is also the most preferred culture; whereas the hierarchy culture is the least current culture and the least preferred culture. The second current culture is the market culture; however, the second preferred culture is the adhocracy culture. The differences between the current cultures and the preferred cultures do not exceed 3.37 degrees. According to Cameron and Quinn (1999, 2006, 2011) there is congruency between the current culture and the preferred culture, so, there is no need for a change. Besides the OCAI, the participants were asked to answer three questions concerns the level of their satisfaction, motivation and the willingness to stay in the school. The answers were scales from 1-6. The average of the answers to the three questions concerns satisfaction, motivation, and the willingness to stay at school, was 5.09 out of 6 (SD 1.612517). This reinforces that the culture in the Druze schools is positive and strong and that there is no need for change. The results of this research can be beneficial for the schools. They will provide a clear picture to the principals and the teachers about their organizational culture. It may strengthen and urge them to put higher goals and visions. It can also urge the principals to make some changes to bridge the tiny gaps between the current and the preferred cultures.

**Keywords:** Organizational Culture; Junior High schools; the Druze sector

---

## 1. Introduction

The organizational culture is a prime instrument by which it is important to start when studying an organization (Fox, 2013). The results of the study help in getting a clearer understanding of the organizational culture. Studies on the organizational culture are needed to identify the kind of cultures and the values that govern the organization (Cameron and Quinn, 2011). Understanding the culture can guide the people to understand many things and can attribute in many processes. It helps to understand the leadership style (Bass, 1985; Mendel et al., 2002; DiPaola et al. 2004; MacNeil and Busch, 2009; Louis et al., 2010; Adeogun and Olisaemeka, 2011; Cameron and Quinn, 2011; Finnigan, 2012; Voight et al., 2013; Gülşen, and Gülenay; 2014; Beauchamp and Parsons, 2012; Herbert, 2011). It helps to predict the level of success in the organization (Voight et al., 2013). It can predict the level of student achievement (Bulach et al., 2011. Mudiwa and Scherz, 2013, Cobb, 2014). It helps to predict teachers job motivation (Freiberg and Stein, 1999) and job satisfaction, and how people feel concerns the organization (Beauchamp and Parsons, 2012; Herbert, 2011). It helps in understanding how things are being operated within the organization (Cameron and Quinn 2011). The organizational culture can provide a "conceptual framework" which accordingly the dynamics of their work can be predicted (Pettigrew, 1979).

## 2. Theoretical Framework

Druze people are a religious group of people that started in Egypt in the eleventh century. There are more than a million and a half Druze people in the world. They live mainly in Israel, Syria, and Lebanon. The religion of the Druze people is secret. They are conservative people. They have their own culture, beliefs, values, traditions, and ceremonies

---

\* Corresponding author. E-mail address: nabila.fadul@gmail.com

(Hirsch and Cicurel, 2010). Lately, however, the Druze community in Israel is changing from a very conservative community into a much more modern one. They are giving up some of their traditions, keeping others (Falah, 2018). In today's modern world, where things are changing quickly in all areas of life including education, and in the Druze sector, it is imperative to revisit the organizational culture in the schools. We live in an age where things change (Anyim, Chidi, and Badejo, 2012). There are fast-growing companies, fast growth factors, practices of fast-growing firms (Bibu, Sala, and Alb, 2016). Knowing the organizational culture in the Druze schools is an essential step that can help the school leaders and teachers to put their visions and take actions in better and more explicit ways. There are about 120,000 Druze residents in Israel. They live mainly in three areas: in twelve villages in the north of Israel, in two villages in the Carmel Mountain and four villages in the Hormone Mountain. In Israel nowadays there are about 30,000 Druze students who study from kindergartens till the universities. About 2.3% of the total number of students in Israel, although the percentage of Druze out of the total population does not exceed 1.6% (Israeli Foreign Ministry website). This study took place in nine schools in northern Israel.

"Organizational culture may be considered as the shared way of being, thinking and acting in a collective of coordinated people with reciprocal expectations; it is shaped, disseminated, learned and changed over time, providing some predictability in every organization." (Serpa, 2016). "The Organizational culture is the shared values, beliefs, and norms that influence the ways employees think, feel and behave toward each other and toward people outside the organization (George and Jones, 2008)." "Organizational culture is a system of values held and conducted by members of an organization which distinguishes an organization from others" (McBain, 2007). The organizational culture indicates which beliefs and behaviors are acceptable and supported to be in the organization and which are not (Dyck and Neubert, 2007). The core components of the Organizational culture are the Shared values, beliefs, traditions, stories, myths, heroes, and the financial arrangements (Wahiba, 2012). The best organizational culture that can influence the employees positively contains values like trust, fairness, support, openness, and supportive communication between the organization and its employees (McBain, 2007). The culture influences the organization (Abrudan et al., 2010). The leaders and the organizational culture are reciprocally connected (Mendel et al., 2002). The Principals, who can motivate the teachers, and make them in alignment with their values and beliefs, are leaders who can create positive organizational cultures; a culture that can bring to the success of the organization (DiPaola et al. 2004). The organizational culture influences the manager's behavior and style (Abrudan et al., 2010). The organizational culture is of crucial importance that if two different organizations share the same organizational culture, they can work together efficiently (Bibu and Haş, 2011). Strong organizational culture can help in achieving cohesion (Bibu and Brancu, 2008). The Druze people have stuck together for a thousand year without having a country of their own. One of the things that helped the Druze people to stick together is their culture which makes the Druze people follow shared values, beliefs, and purpose (Hirsch and Cicurel, 2010). The school organizational culture is essential for achieving the goals of the schools, and it is essential that it is planned and cared for. "The image or reputation of the organization and organizational culture must be assessed, controlled and directed towards achieving goals" (Bibu and Mos, 2012).

### **3. Methodology**

#### *3.1. Method*

To find out the current organizational culture of the schools, and to find out the preferred organizational culture, the OCAI was used. The OCAI is a practical, efficient, involving manageable, valid and a useful instrument that was used in many studies in education (e.g., Fralinger and Olson, 2007; Kalliath et al., 1999). The OCAI was designed to identify the dominant culture of an organization by profiling that organization across a quartet of organizational culture types: clan culture, adhocracy culture, market culture, and hierarchy culture (Cameron and Quinn, 2011. p. 75). The OCAI instrument is organized into "Now" and "Preferred" sections. Each of these two sections is formed of 6 items that demand the participants to rate their workplace along six organizational dimensions: (a) dominant characteristics, (b) organizational leadership, (c) management of employees, (d) organizational glue, (e) strategic emphasis, and (f) criteria of success. Each of these six items demands the participants to rank four descriptive statements regarding the applicability of that statement to the participants' workplace. Participants must arrive at a total of 100 points for these four descriptors before moving on to the next question. The "Now" section shows the current dominant organizational culture while the "Preferred" section of the instrument expresses how the employees would like their school to function 5 years later. If the difference between "Now" and "Preferred" is 10 points or more, in any of the four organizational culture types: the clan, adhocracy, market, and hierarchy cultures, urgent action is required (Cameron and Quinn, 1999, 2006, 2011).

#### *3.2. Subjects*

The study was conducted in the year 2018 in the Junior High School in the Druze sector in the Upper Galilee in northern Israel. Its purpose was to examine the organizational culture of the schools. For this purpose, the "Organizational Culture Assessment Instrument" (OCAI), developed by Cameron and Quinn (1999, 2006, 2011) was used. The sample size for this study consisted of 220 staff members. They were from 9 different Junior High schools. Subjects for the OCAI pilot study were schools staff: principals, vices, coordinators, homeroom teachers, counsellors, teachers with no other roles, integration teachers, secretaries, librarians and other staff members. The questionnaires



were distributed to most of the staff who attended at the days when the researcher went to the schools to distribute the questionnaires. Some people did not agree to fill it in, others took the questionnaires and did not hand it back. 300 copies were distributed. 220 copies were collected.

### 3.3. Measures

The survey included demographic and empirical items. It had three sections. Section one: the demographic items which included: (a) gender (b) religion (c) subject of teaching (d) years of teaching (e) role in the school (principal, vice, coordinator, homeroom teacher, counsellor, teacher with no other roles, secretary, librarian, integration teacher, another subject, other) (f) being or not being a management member (g) certificates (matriculation, BA, MA, PhD, or other) (h) latest studies (i) classes the teacher teaches. Section two: three questions concern the level of satisfaction, the level of motivation and the willingness to stay in the school. These three questions were scaled from 1-6. Section three: the Organizational Culture Assessment Instrument (OCAI) Cameron and Quinn's (1999, 2006, 2011).

## 4. Discussion of the OCAI Results

Concerns the current culture, the school staff rated the clan culture as the dominant culture that they have now, and also gave considerable points to the other cultures as follows: (Mclan = 27.74, SDclan = 6.86; Madhocracy = 24.20, SDadhocracy = 3.89; Mmarket = 24.55, SDmarket = 5.92; Mhierarchy = 23.45, SDhierarchy = 4.85). The difference across the ratings is highly significant  $\chi^2(3, N = 220) = 99.89, p < 0.001$ . Concerns the preferred culture, the school staff also rated the clan culture as the culture that they prefer to have in five years, but also gave considerable points to the other cultures as follows: (Mclan = 31.11, SDclan = 7.72; Madhocracy = 25.81, SDadhocracy = 4.94; Mmarket = 21.74, SDmarket = 5.61; Mhierarchy = 21.47, SDhierarchy = 4.87). The difference across the ratings is highly significant  $\chi^2(3, N = 220) = 312.109, p < 0.001$ . The results are clarified in the table and figure below.

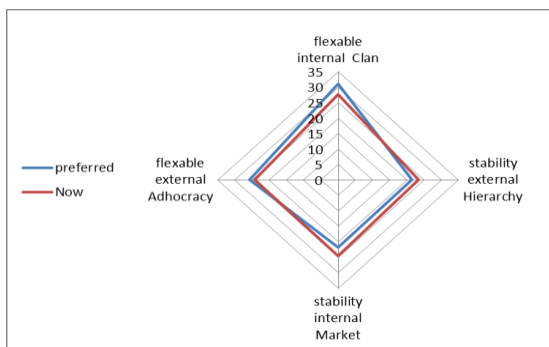


Figure 1. The organizational culture in the Druze sector

	current	Preferred	Difference
Clan	27.74	31.11	3.37
Adhocracy	24.20	25.81	1.61
Market	24.55	21.74	-2.81
Hierarchy	23.46	21.47	-1.98914
	100	100	

Figure 2. The organizational culture in the Druze sector

Figure 1 and Figure 2 show the findings for the organizational culture in the Druze Junior High schools in Northern Israel. The current dominant organizational culture is the clan culture (Mclan = 27.74) whereas market (Mmarket = 24.55) and adhocracy (Madhocracy = 24.20) come next with a very small difference between them which is 0.35 for the advantage of the market. And after that, the last one which is the hierarchy (Mhierarchy = 23.45) with a difference of 0.75 point from the adhocracy. In other words, the clan culture seems to be the most dominant culture with the difference of 3.19 from the market, which is considered a slight difference (Cameron and Quinn, 1999, 2006, 2011). As it appears, the other three cultures, the market, adhocracy and the hierarchy cultures are almost equal with the differences of a fraction of a number. So, and as it seems, the current school culture is a mixture of all the four cultures.

By looking at the expected culture in the Druze schools in five years, it appears that the clan culture is the most dominant culture (Mclan = 31.11). The difference in average between the current and expected for the clan culture is 3.37. The difference between the preferred clan culture and the least wanted culture which is the hierarchy culture is 9.64 degrees. The findings also show that there is an increase in adhocracy (Madhocracy = 25.81) which is the second desired culture by teachers and employees in their schools. However teachers and employees in the Druze sector want to reduce the hierarchy culture (Mhierarchy = 21.47) and the market culture (Mmarket = 21.74). They want to reduce the market with 2.81 degrees and the hierarchy with 1.98 degrees.

Figure 1 adds the flexibility versus stability and the external versus internal dimensions mentioned in Cameron and Quinn (1999, 2006, 2011). The findings show that the expectations of the school staff for organizational internal focus and external focus are balanced whereby the clan and the adhocracy cultures are the dominant cultures expected by teachers. They also want a flexible and carefree culture but still stable and under control.

#### 4.1. The dominant values in the Druze schools according to OCAI

According to the results, the clan culture is the current dominant culture with also measurable rates for the other cultures. In other words, the Druze current dominant school culture is the clan culture, while the other three cultures appear to exist in the schools. This implies that the Druze organizational culture includes values from the four cultures but with different proportions. When looking at the values that each culture supports according to Cameron and Quinn (2011), the following values that express the clan culture appear to be dominant in the Druze culture: loyalty, commitment, cohesion, morale and being friendly. The leaders are considered to be mentors and parent figures. As it appears, the clan culture is the current dominant and the preferred culture. So, the participants are happy with the current organizational culture, and they have the clan values, and they want to strengthen them more. The participants also perceived that their schools have market culture, which is the second current culture. According to the market values mentioned in Cameron and Quinn, (2011), the Druze culture is also goal/results-oriented. People are competitive. The leaders, besides of being mentors, are also hard drivers, producers, competitors and demanding. They give significant importance to winning, reputation and success. The results that they are demanding are the high student achievement. They are competitive with other schools which are: the other Druze schools, the Arab schools, and the Jewish schools. According to the preferred results, it seems that the participants want to reduce the market culture. The Adhocracy Culture appears to exist in the schools with close proportion to the market culture. The adhocracy values that appear to be in the Druze organizational culture are: commitment, innovation, creativity, growth, and being dynamic. The organizations encourage individual initiative and freedom. According to the preferred results, the Adhocracy Culture is the second preferred culture after the clan culture. The least culture that they have and they want to have less of it is the Hierarchy Culture: according to the results, the schools are governed by procedures, stability; formal rules and policies. The leaders are perceived to a certain extent, as coordinators and organizers (M23.46); however, in less proportion to the other three cultures. Moreover, also, according to the preferred, the participants want to reduce this culture to (M21.47).

#### 4.2. Discussion of the Demographic Data

Concerns the age of the teachers and the employees, almost half of them are more than 40 years old. The average age of the teachers and the employees is 39.7, SD=9.25. Also, the average seniority is 14.9, SD=9.8. Most of the respondents have teaching and working experience of 16 years or more which is 39.55% of the respondents. Riordan, Griffith, and Weatherly, 2003 (as cited by Badawy et al., 2017) suggested that the age and the seniority influence the organizational culture. He explained that older workers or those with longer tenure are more likely to become "emotionally attached" to their organizations. Wofford, 2003 (as cited by Badawy et al., 2017) suggested that there is a positive correlation between age, tenure and job satisfaction. The results of this research strengthen his suggestion. So it can be suggested that one reason for the similarities in the current and the preferred culture (the clan culture) is the percentage of the teachers who are older than 40 years and have seniority more than 16 years.

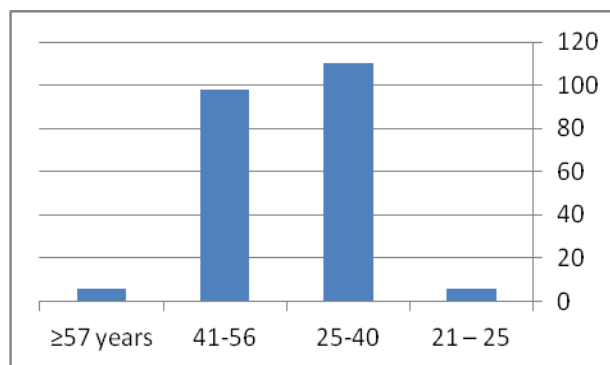


Figure 3. Age of employees

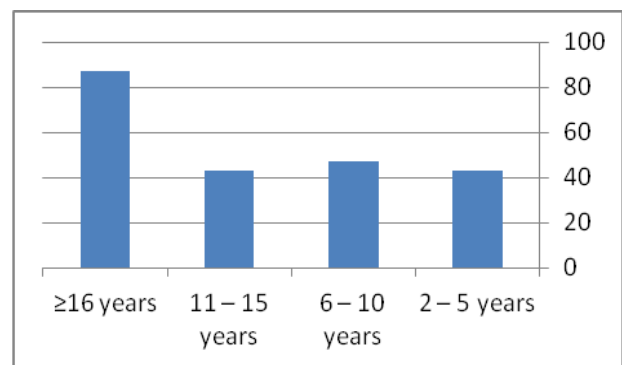


Figure 4. Years of seniority

Out of 220 teachers, 88.18% were reported to be females, and the remaining 11.82% were males. Sempane et al. 2002, Romaine, 1999 and Wofford, 2003 (as cited by Badawy et al., 2017) found that the gender does not affect the organizational culture. The three questions concerns satisfaction, motivation, and the willingness to stay at school were scaled from 1-6. The average of satisfaction is 4.97, SD= 1.24. The average of motivation is 5, SD= 2.02. The average of willingness to stay at the same school is 5.3, SD=1.57. There were no differences among religion.

The Following is a table that includes all the demographic analysis.

Characteristic	Number	%	Teaching Experience		
<b>Gender</b>			2 – 5 years	43	19.55%
Male	26	11.82%	6 – 10 years	47	21.36%
Female	194	88.18%	11 – 15 years	43	19.55%
Total	220	100.00%	≥16 years	87	39.55%
<b>Age</b>			Total	220	100.00%
21 – 25	6	2.73%	<b>management member</b>		
25-40	110	50.00%	Yes	35	15.91%
41-56	98	44.55%	No	185	0.840909
≥57 years	6	2.73%	Total	220	100.00%
Total	220	100.00%	<b>Certificates</b>		
<b>Religion</b>			Matriculation	10	4.55%
Druze	188	87.27%	BA	127	57.73%
Christian	26	10.00%	MA	81	36.82%
Muslim	6	2.73%	PhD	1	0.45%
Total	220	100.00%	other	1	0.45%
			Total	220	100.00%

Figure 5. Demographic Profile of Respondents

## 5. Conclusions

In the light of the empirical analysis data regarding the structural validity of the research scale, it is possible to judge that the OCAI is a highly credible tool that can be applied to the Druze Junior high schools. The current and the preferred culture in the Druze schools is the clan culture, the second current culture is the market, which is not the preferred. The third current culture is the adhocracy culture, and it is the second preferred culture. The hierarchical culture is the least existing culture, and it is also the least preferred one. The results show that the following values are apparent in the organizational culture and are also preferred: loyalty, commitment, cohesion, morale, competitiveness, innovation, creativity, growth, being friendly, results-oriented, initiative, and dynamic. The results indicate that the human development resource is apparent within the values and the culture of the schools. The works are carried out within the spirit of a team, consensus, and participation; the individuals have the commitment, mutual respect, and high trust. The differences between the cultures are not very significant. According to Cameron and Quinn (2011), these differences do not require changes. According to the findings, the participants who filled out the questionnaires are satisfied and motivated. There are two evidence that indicate that the organizational culture is positive: first, the results of the OCAI questionnaire, and second, the results of the answers on the three questions concerns satisfaction, motivation, and the willingness to stay at school. The average of the three questions was 5.09 out of 6.

## Recommendations

A strong organizational culture where the members are satisfied with what they have can be motivating and inspiring. The leaders can arrive at higher levels of excellence and uniqueness, and can enable the schools to think of higher goals and visions which achieving them can be more comfortable than in an organization where the organizational culture is weak. The results of this research are significant for the schools. They can give the principles a more precise picture about how the teacher and the workers perceive their organizational culture and how they prefer it to be. Because there are only slight differences between the current and the preferred culture, the principals can learn these results; think what they can do to bridge the gaps and improve the organizational culture, which is very strong and encouraging. It is true that according to Cameron and Quinn (2011), there is no need for changing the organizational culture when the differences are less than 10, but, because the results are very encouraging, the leaders can think of specific ways to implement some changes that can improve the culture in their school. The leaders can bring their employees to work harder and harder. Also, understanding the organizational culture can be the basis for developing various programs that can help to achieve the organizational goals for better quality. Studies on the organizational culture can be used as a reference in the future studies. A recommendation for a future study is to make interviews with the principals of the schools that the OCAI was held on concerns their leadership styles. The need of this is to find out which leadership styles are used by the principals and that make the teachers perceive that the current culture is the clan culture and it is also the preferred.

## References

- Abrudan, M. M., Matei, M. C., Schiopoiu-Burlea, A. S., DĂNĂIAȚĂ, D., SÎRBU, M. ROȘCA, D., (2010). The implications of cultural dimensions on business practices and managerial behaviour within the organizations of Bihor country. *The Annals of The "Ștefan cel Mare" University of Suceava. Fascicle of the Faculty of Economics and Public Administration Vol. 10, Special Number*
- Bass, B.M. (1985). Leadership and Performance beyond Expectations. *New York: The Free Press*.
- Beauchamp, L., and Parsons, J. (2012). Instructional leadership in Alberta: Research insights from five highly effective schools. *AASA Journal Of Scholarship and Practice*, 8(4), 41-50.
- Bibu N, Sala, D., and Alb, M., (2016). The role of strategic/ or operational choices in the management of Romanian fast growing firms. Decision-making and investment decisions. *The 2nd International Scientific Conference SAMRO*. pp. 20-25.
- Bibu, N.A. and Brancu, L., (2008). Convergences of the Romanian societal culture with European culture clusters in the process of European integration. *The role of intercultural teams management in increasing European cohesion*. [Online] Available from: <http://ssrn.com/abstract=1156343> [Accessed 26/05/18]
- Bibu, N.A. and Mos, L. A., (2012). Leadership Style in the Romanian Public Institutions – the Case of City Halls. *Review of International Comparative Management*. Volume 13, Issue 1, pp. 81-87.
- Bulach, C. R., Lunnenberg, F. C., and Potter, L. (2011). Creating a culture for high performing schools: *A comprehensive Approach to School Reform and Dropout Prevention* (2ed. Ed.). Rowman and Littlefield Education.
- Cameron, K. S., & Quinn, R. E. (1999). Diagnosing and changing organizational culture. Reading: *Addison-Wesley*.
- Cameron, K. S., and Quinn, R. E. ( 2011). Diagnosing and Changing Organizational Culture: *Based on the Competing Values Framework, 3rd Edition*. San Francisco, CA: Jossey-Bass.
- Cameron, K. S., and Quinn, R. E. (2006). Diagnosing and changing organizational culture: *Based on the competing values framework*. San Francisco, CA: Jossey-Bass.
- Cobb, N. (2014). Climate, culture, and collaboration: The key to creating safe and supportive schools. *Techniques: Connecting Education and Careers*, 89(7), 14-19.
- DiPaola, M., Tschannen-Moran, M., and Walther-Thomas, C. (2004). School Principals and special education: *Creating the context for academic success*. (Cover Story). *Focus On Exceptional Children*, 37(1), 1-10.
- Dyck, B. and Neubert, M. J. (2007) Principles of Management. *International student edition*. Library of Congress Control. Printed in China.
- Falah, J.,F. (2018), Does Multicultural Education Affect the Druze Heritage Curriculum? *Open Journal of Social Sciences*. Vol.06 No.01 Article ID:82119,15 pages. Available from: 10.4236/jss.2018.61019 [Accessed 11/05/18]
- Finnigan, K. S. (2012). Principal leadership in low-performing schools: A closer look through the eyes of teachers. *Education and Urban Society*, 44(2), 183-202. doi:10.1177/00131245111431570. For Convention.
- Fox, J. R. (2013). Analyzing the organizational culture of Yolo County using two assessment models (Doctoral dissertation, California State University).
- Fralinger, B., & Olson, V. (2007). Organizational culture at the university level: A study using the OCAI instrument. *Journal of College Teaching & Learning*, 4(11), 85-98.
- George, J.M., and Jones, G.R. (2008). Understanding and Managing Organizational Behavior (Fifth Edition). *Upper Saddle River: New Jersey, Pearson Prentice Hall*.
- Gülksen, C., & Gülenay, G. (2014). The principal and healthy school climate. *Social Behavior and Personality: An international journal*, 42, S93-S100
- Guramatunhu-Mudiwa, P., and Scherz, S. D. (2013). Developing psychic income in school administration: The unique role school administrators can play. *Educational Management Administration and Leadership*, 41(3), 303-315. Doi: 10.1177/1741143212474803
- Herbert, Elizabeth B. (2011). "The relationship between emotional intelligence, transformational leadership, and effectiveness in school principals". *Educational Policy Studies Dissertations*, Paper 66. [http://scholarworks.gsu.edu/eps\\_diss/66](http://scholarworks.gsu.edu/eps_diss/66) [Accessed 5/05/18]
- Hirsch, T. and Cicurel, E., (2010). Identity and belonging as coping resources for Druze adolescents during the Second Lebanon War. *Mifgash: Journal of Social-Educational Work*. pp 61-85. Hebrew source.
- Israeli Foreign Ministry website. *A Window on Israel - The Druze in Israel*. <http://mfa.gov.il/MFAAR/InformationaboutIsrael/TheIsraeliSociety/Pages/Focus%20on%20Israel-%20The%20Druze%20in%20Israel.aspx> [Accessed 23/07/18]
- Kalliath, T. J., Bluedorn, A. C., & Gillespie, D. F. (1999). A confirmatory factor analysis of the competing values instrument. *Educational and Psychological Measurement*, 59(1), 143-158.
- Louis, K.S., Leithwood, K., Anderson, S., and Wahlstrom, K. (2010). Investigating the Links to Improved Student Learning. New York, NY: The Wallace Foundation.
- MacNeil, A., Prater, D., and Busch, S. (2009). The effects of school culture and climate on student achievement. *International Journal of Leadership in Education: Theory and practice*, 12:1, 73-84. Retrieved from <http://dx.doi.org/10.1080/13603120701576241>.
- McBain, R (2007). 'The practice of engagement: research into current employee engagement practice', *Strategic HR review*, vol 6, no 6, pp 124-136.
- Mendel, C. M., Watson, R. L., MacGregor, C. J., (2002). A Study of Leadership Behaviors of Elementary Principals Compared With School Climate. *Southern Regional Council for Educational Administration*. <https://files.eric.ed.gov/fulltext/ED471556.pdf> [Accessed 1/06/18]
- Voight, A., Austin, G., and Hanson, T. (2013). A climate for academic success: *How school climate distinguishes schools that are beating the achievement odds (Report Summary)*. San Francisco: WestEd.
- Wahiba, I., (2012). The impact of organizational culture on job satisfaction. Case study of the paramedical group in the public hospital of Terabi. Faculty of Economic Sciences, *Commercial Sciences and Management*
- Sandro Serpa , 2016. An Overview of the Concept of Organisational Culture. *International Business Management*, 10: 51-61.

## Population ageing, a consequence of transition

Mihaela-Camelia Schmidt\*

*University of Petrosani, 20, University Street, 332006, Romania*

---

### Abstract

The paper contains a statistical analysis of data provided by literature in the field regarding the demographic phenomenon of population ageing and the multiple implications of this demographic tendency that represents a challenge for all the states of the world.

*Keywords:* old age, ageing process, demographic ageing

---

### 1. Old age and the ageing process

Ageing is a process that turns a vigorous adult into a fragile individual, vulnerable to most diseases and even to the risk of death (Prada, 2001, pag. 11). For the majority of specialists in demography, ageing means the growth of the ratio of old population in the total population.

Ageing is a process that generates a series of functional disturbances and deviations, associated with numerous structural alterations. It is not synonymous with old age, the latter being an age span (60/65 years old and over) characterized by profound degradation and involution of the main functions of the human body, among which the decline of physical and mental capacities, the decrease of resistance to diseases, the diminishing of the adaptation capacity, etc. (Rădulescu, 2002, pp. 63-64).

The issue of the vulnerability of the elderly is dealt with in most research in the field, mainly from the perspective of the biological/physiological, psychological and social changes brought about by ageing. Apart from the problems generated by these changes, elderly persons also face financial, material, and medical difficulties. The main biological (organic) alterations characteristic of ageing affect primarily the nervous system, followed by the locomotor, the cardiovascular, the respiratory, the renal and the reproductive systems. There are also skin changes, (aspect and color), sensory deteriorations (sight, hearing, etc.), reduction of the muscular tonus, of the effort capacity, digestive disorders, etc. Psychological changes become obvious with old age, manifesting themselves from the elementary mental processes (on a sensory level) to the most complex that define the human being (language, thought, attention, etc.). (Bucur & Maciovan, in Neamțu, 2003, pag. 914-916) from a social point of view, old age is equivalent with disengagement from active social roles, withdrawal from professional life and adoption of other social roles (Rădulescu, 2002, pag. 66).

### 2. The demographic ageing of population

Population ageing is a phenomenon that appeared as early as the last century, as a result of the decrease of mortality, the control of infectious diseases the improvement of the sanitary system and the progress of medicine, the higher living standard and better nutrition (Curaj, în Neamțu, 2010, pag. 281). The increase of the elderly population is a challenge for all the states of the world when it comes to managing the issues pertaining to old age. Although Romania has a population with a relatively balanced group structure, the increase of the elderly population follows the same international demographic trend. Literature in the field consider people of 60, 65, and over to be part of the elderly population.

In order to understand the evolution of the demographic ageing phenomenon in time, it is important to analyze the researchers' opinions regarding Romania's demographic projection for the next decades. Numerous studies analyze the demographic evolution of Romania's population (in the present, the past, and the future).

---

\*Tel 0040722255366, E-mail: schmidtcamelia@yahoo.com

In this context, Cornelia Mureşan's study divides the population into homogeneous age and gender sub-groups. This projection reveals a constant decrease of Romania's population on account of decreasing birth rate, (and consequently, decreasing young and adult population) and of increasing number of elderly persons aged 60 and over (see table 1).

Table 1: Projection of Romania's population (and of its demographic structures) until 2030

Population*	1990	2000	2010	2016	2030**
Total population (thousands)	23,207	22,435	20,247	19,703	18,671
Percentage compared with 1990	100	96.67	87.24	84.90	80.45
Births during the year (thousands)	314	234	212	188	137
Young between 0-19 years old (thousands)	7,348	5,760	4,322	4,139	3,236
Percentage of young between 0-19 years old	31.66	25.67	21.35	21.01	17.33
Adults between 20-59 years old (thousands)	12,226	12,455	11,417	10,747	10,974
Percentage of adults between 20-59 years old	52.68	55.52	56.39	54.54	58.77
Elderly aged 60 and over (thousand)	3,633	4,220	4,508	4,817	4,460
Percentage of elderly aged 60 and over	15.65	18.81	22.26	24.45	23.89
Percentage of females	50.7	51.10	51.30	51.2	52.20
Percentage of males	49.3	48.90	48.70	40.8	47.80

\* Population on July 1 of the respective year

Sources: Mureşan, 1999, pag. 2012

NIS (National Institute of Statistics), Romania's Statistical Yearbook, 2017

The group of elderly population, aged 60 and over, increases in Romania especially after the Second World War, doubling its ratio between the 1930's and the beginning of the 70's. Then, there is a stagnation of increase until the beginning of the 90's, when the ageing rate accelerates again (Mureşan ş.a., 2009, pag.5).

The ratio of elderly persons in the total population increases constantly over the past decades from 15.65% in 1990 to 24.45% in 2016 (table 1). In the same period, the number of young decreases from 7,348,000 individuals to 4,139,000 in 2016, whereas the ratio of adult populations in the total population follows an ascending trend until 2010 (when it reaches the level of 56.39%, to undergo a later decrease to 54.54% in 2016).

Thus, the growth of the ratio of the elderly population (demographic ageing) is determined not only by the increase of the number of elderly, but also by the change of the proportion between different age segments of the population, always alongside with other evolutions, such as: the decrease of the percentage of young, the increase of the number of adult population, etc.

Apart from the size of the elderly population, the structure of the elderly population according to several variables (gender, residence environment, level of training, etc.), the degree of ageing, etc., there are also other indicators of ageing that can induce different classifications, namely the demographic ageing index and the parental support index.

The parental support index is meant to reveal the impact of population ageing on the family. Starting from the premise that the elderly need permanent care, and the responsibility of this care is attributed to the direct descendants, the parental support index expresses the ratio between the number of elderly persons aged 80 and over, and the number of "elderly adults" in the age group 55-64 years old. According to this index, on a national level there are approximately 23 elderly persons for every 100 "elderly adults" (op. cit., pag. 21).

Having a universal character, population ageing affects societies on every level, Romania being no exception, and the social and economic consequences of this process are difficult to assess.

Some of the major consequences of population ageing are the following: the challenge for the welfare services by increasing the expenses necessary for the social programs for the elderly to the detriment of other expenses allocated to other age segments of the population; the financial overloading of the pension system by the increased number of beneficiaries and the decrease of the number of contributors to the pension fund; increasing expenses in the health system, which generally grow with the number and the age of the elderly; the decline of the modern society of western type by loss of dynamism, of the capacity for innovation and progress; the decline in the number of population, etc. (op. cit., pag. 7).

The implications of the demographic ageing tendency are multiple and have consequence on different levels (Curaj, in Neamtu, 2010, pp. 294-296):

1. On a financial level. It is known that the number of elderly persons does not coincide with that of pensioners, the latter representing the larger proportion, the explanation being that the category of pensioners also includes persons who acquire this status earlier than the beginning of old age (for example: employees in the mining industry, in the military or the police force, etc.). Financial issues occur due to the fact that the ratio of pensioners grows gradually and the ratio of the employed decreases, so that every employed person must pay higher and higher contributions to the pension fund. On the other hand, it is known that, in the families headed by persons of 60 or over, income is lower than in the families headed by adult persons. This is explained by its source, since it primarily comes from social services (mainly pensions), whereas the adults get their income from salaries, the difference being obvious if we take into account the difference between the value of pensions and that of salaries. In close correlation with the income level, the expenses of the households headed by elderly persons are lower than with those headed by adults. Most of the consumption expenses of the elderly is represented by expenses for food and non-alcoholic beverages, followed by household related expenses (water, electricity, gas). These two categories of expenses, alongside with those dedicated to health issues, represent a higher ratio with the elderly than with the adults;
2. On a health level. Romania's economic and social evolution in the transition period had a strong impact on the demographic and health status of the population. Although there has been preoccupation for improving the population's health and the providing of suitable medical services, the health status of the Romanian population is still precarious in certain respects. On the other hand, due to higher life expectancy, the number of elderly persons grows, which leads to an increasing number of ill persons, especially suffering from chronic diseases (heart and respiratory diseases, diabetes, osteoporosis, etc.) and mental conditions (dementia, depressions, anxiety, etc), old age being known to be characterized by polypathology;
3. On a social welfare level. Having in view the increasing number of elderly, with their specific problems, the number of persons in need of support from social welfare services increases. The lower the healthy life expectancy, the heavier the 'burden' for the health services and the pension system, and the political decision-makers should be prepared to take adequate measures in order to deal with the needs of elderly persons. On the other hand, although most of the elderly live independently or are taken care of by their family, an increase in the number of elderly persons committed to specialized institutions has increased over the past years. Among the social services provided to the institutionalized elderly there are: support for household cleaning, juridical and administrative counseling, ways of preventing social marginalization and social reintegration according to the psycho-affective capacity.

Consequently, population ageing has an objective and virtually irreversible character, being one of the consequences of demographic transition, that is of the shift from traditional high fertility and mortality regimes to modern low fertility and mortality regimes. It is a steady and long process, both present and future, still not completed in any country in the world. However, the rate of ageing can be slower or faster depending on the evolution of its major determining factors – fertility and migration. It is a universal phenomenon which affects everybody. The growth of the number of elderly in comparison with the working population has direct repercussions on the equity and solidarity between generations. Ageing involves the increase not only in the ratio, but also in the absolute number of elderly.

## References

- Bucur V., Maciovan A, *Probleme ale vârstei a treia*, în Neamtu G. (coordonator), *Tratat de asistență socială*, Editura Polirom, Iași, (2003).
- Cernescu, T., *Sociologia vârstei a treia*, Editura Beladi, Craiova, (2004).
- Consiliul National al Persoanelor Vârstnice (CNPV), *Situația persoanelor vârstnice din România*, mai, (2015).
- Curaj A., *Persoanele vârstnice: definire, caracteristici, probleme specifice*, în Buzducea D. (coordonator), *Asistența socială a grupurilor de risc*, Editura Polirom, Iași, (2010).



- Fontaine, R., *Psihologia îmbătrânirii*, Editura Polirom, Iași, (2008).
- Institutul Național de Statistică (INS), *Anuarul Statistic al României*, (2017)
- Mureșan Cornelia, *Evoluția demografică a României. Tendințe vechi, schimbări recente, perspective (1870-2030)*, Editura Presa Universitară Clujeană, (1999).
- Mureșan C. ș.a., *Raport privind situația vârstnicilor din România*, Centrul de Studiere a Populației, Universitatea Babeș-Bolyai, Cluj Napoca, 2009.
- Schmidt, M.C., *Politici pentru persoanele vârstnice – note de curs*, Tipografia Universității din Petroșani, (2011).
- Sorescu, M. E., *Asistența socială a persoanelor vârstnice*, Editura Universității din Craiova, (2005).



# A combinatorial gray wolf optimization algorithm for finding 2D protein conformation

Ioan Sima<sup>a</sup> \*

<sup>a</sup>“Babes-Bolyai” University, str. M. Kogalniceanu, nr. 1, Cluj-Napoca, nr. 1 RO-400084, Romania

---

## Abstract

Protein folding problem is one of the exciting subjects in the bioinformatics field. It consists in finding tertiary or quaternary structure from an amino acid sequence. Gray Wolf Optimization (GWO) algorithm is a new meta-heuristic method dedicated to solving optimization problems with continuous functions. In this paper, we propose a novel variant of Gray Wolf Optimization algorithm for finding the optimum of combinatorial functions (cGWO). This variant includes crossover operation taken from evolutionary methods. In our proposal, it is applied for solving protein folding in HP 2D model, which is a combinatorial problem. Furthermore, Protein Folding is NP-complete problem. Results of experiments have shown that the proposed cGWO has a weak convergence. However, the best known energy in the literature was reached in this study. Energy conformations close to optimum are obtained from the first iteration if the size population is large enough.

**Keywords:** Grey Wolf Optimisation; Combinatorial optimization; Protein Folding; 2D HP Model; Crossover; Bioinformatics;

---

## 1. Introduction

The proteins are one of the most important constituents of living matter. They are epigenetic expression of the cellular genome (Dinu et al, 2006). They perform and control the essential functions in living cells and organisms. Therefore, the knowledge of the structure and their functions is essential to understanding the functioning of the living.

The tertiary or quaternary structure (also called native conformation or folded protein) is difficult to predict because the space of the possible conformations is huge and complex. This is known as *protein folding problem*.

At the molecular level, the proteins are linear polymers formed from 20 types of  $\alpha$ -amino acids (aa), called proteinogenic amino acids. The length of the proteins varies from a few tens to a few thousand, even tens of thousands of aa. Thus, the molecular mass varies from hundreds to millions of u.a (Dalton).

Amino acids have similar chemical structures. These differ by the degree of hydrophobicity, charge and size.

Levinthal outlines the principle according to which the native conformation can be predicted only from their linear sequences (Levinthal, 1969).

Over time, several models have been created for the representation of protein conformations. One of the simplest and coarser models, but one that still captures the essence of the folding phenomenon, was proposed by Lau and Dill, 1989. It has two simple forms: square or 2D - used in this paper - and cubic or 3D type, closer to the real protein.

To solve protein folding on this model, so far, it has been proposed a lot of computational methods. In Unger and Moulton, 1993, it was applied a genetic algorithm (GA) with a form of simulated annealing (SA) and Turabieh used a hybridized GA with a form of local search (LS) called Great Deluge Algorithm (Turabieh, 2016).

It was also proposed an Ant Colony Optimization Algorithm (ACO) with the 2D and 3D Model (Shmygelska and Hoos, 2003, 2005). In the same way, it has been proposed an improved hybrid algorithm which is a mix between particle swarm optimizer (PSO) and tabu search (TS) and it is used for prediction protein structure for 3D HP lattice (Zhou et al, 2013). In Czibula et al, 2011, it is found a Q-learning approach for solving the 2D HP lattice.

The Grey Wolf Optimization (GWO), a new inspired of nature algorithm, was proposed by Mirjalili et al, 2014. Initial, it was created for solving continuous functions. Madadi and Motlagh, 2014, used it for optimal tuning of proportional-integral-derivative (PID) controller parameters for DC Motor drive to find the global optimum solution in search space and Yassien applied the GWO to the 0/1 Knapsack Problem (Yassien et al, 2017).

---

\* Corresponding author. Tel.: +4-074-584-9607

E-mail address: sima.ioan@cs.ubbcluj.ro.

Lu et al, 2016, changed the GWO for the approach of combinatorial issues. This variant, named by them, MODGWO, is a multi-objective discrete grey wolf optimizer used for scheduling problem in welding production. The authors modified the search operator developed in originally GWO for solving continuous optimization problems, with a mutation shift variant. Also, the GWO has been modified for approach the binary problem for feature selection (Emary et al, 2016).

After this state of the art, we can say that the GWO algorithm has not yet been applied for solving the protein folding problem.

This paper is organized as below. After this introduction, the next Section presents briefly the protein folding problem. In Section 3, we will describe in very short details the Grey Wolf Optimization (GWO) algorithm for continuous function. Then a modified GWO algorithm, adapted for combinatorial function, that we called cGWO, is proposed in this paper for solving the 2D HP model. This model will be explained in Section 4. In Section 5, we will analyze the results of our experiments. The last section contains the conclusions and further work.

## 2. Protein folding problem

There are 20 proteins genic (protein-building) amino acids (aa), which differ one from another by the nature of side chain R. Biochemical notation uses three letters, while bioinformatics uses a single English letter for its representation.

The proteins (also called protein sequences) are linear chains of  $\alpha$ -amino acids. The proteic macromolecule has four levels of organization: primary structure, secondary structure, tertiary structure, and quaternary structure (Mihalaş, 2011).

Primary structure is the amino-acid sequence, poly-peptide chain being represented as an ASCII string in bioinformatics.

Secondary structure is made of by regularly repeating local substructures ( $\alpha$ -helix,  $\beta$ -sheet, turns) stabilized by hydrogen bonds.

Tertiary structure is the overall shape of a single protein macromolecule, representing the spatial (3-D) relationships of the secondary structures to one another. A synonym term to tertiary structure is fold – it enables the basic function of a protein.

Quaternary structure is sometimes formed by several protein molecules (called protein subunits) which function as a single protein complex.

Protein folding is the physical process through which their uni-dimensional primary structure becomes three-dimensional tertiary (or quaternary) one, by means of a sequence of twists, bends, and bundles. Most proteins fold into unique 3-dimensional structures and the shape of the natural folding process is called native conformation. In the case of small proteins, the folding process acts spontaneously, both in vivo and in vitro.

Native (or folded) protein conformation is difficult to predict.

Due to its numerous applications in genetic engineering and medicine, the prediction protein structure folded, starting from its primary structure is one of the greatest challenges of current bioinformatics research.

To solve it, this problem has been addressed from the perspective of several algorithms applied on series simple or more complex models.

## 3. HP 2D Lattice Model

One of the most popular considered models is HP model, which was proposed by Lau and Dill in 1989. This model introduces a series of simplifications.

First, HP being a coarse model, the units that are represented on lattice are the amino acids, not atoms.

Second, the 20 proteinogenic amino acids are classified only into 2 classes: H (hydrophobic) and P (polar, or hydrophilic). The H amino acids reject the water and P amino acids attract the water. Due to the fact that the globular proteins are submerged in an aqueous internal environment of living organisms, they will form a hydrophobic core, as can be seen in fig 3. Thus, it will have an alphabet composed by 2 letters, {H, P}, between which it can form up to 4 types of contacts: H..H, H..P, P..H and P..P.

The third, the space is discretized in very simple lattices. For bi-dimensional lattices, the simplest space is the square and for tri-dimensional lattices a simple space is the cube. In these spaces, amino acids can be rotate with exactly 90 degrees. The encoding of directions of amino acids can be absolute or relative. In our work, we are focused on experimenting in 2D space, where amino acids can be rotate with 90, 180 or 270 degrees and it was used the absolute encoding of directions. In this way, the directions are: Right – R(0), Down – D(1) Left – L (2), and Up – U(3). For 2D HP model and absolute encoding, it will have an alphabet of directions composed by 4 letters: {L; R; U; D}.

The fourth, the energy of the HP model is a convention which reflects the fact that H aa to form a hydrophobic core. Thus, for each pair of non-consecutive H (H..H) aa in the protein sequence, but which are adjacent on the lattices (topological neighbors), the energy of conformations decreases with a value,  $e$ , equal to -1. For the other three types of contacts (H..P, P..H, P..P), the value of  $e$  is considered equal to 0. In fact, the energy of conformation is the number of contacts between H...H aa that are not consecutive in sequence (see fig. 3).

These being given, the folding protein problem, in HP models, can be defined as a problem of combinatorial optimization.

The HP sequence is given as:  $s=s_1s_2s_3..s_i..s_n$ , where:  $n$  – no of aa;  $s_i \in \{H, P\}$ ; the native conformation is the conformation which has the minimum energy,  $c_m$ , of sequence  $s$ , where  $c_m \in C(s)$ , and  $C(s)$  – the set of feasible conformations of the sequence  $s$ .

The energy of conformation  $c_m$ ,  $E(c_m)$ , is:

$$E(c_m) = \min\{E(c) \mid c \in C(s)\}, \text{ where } E(c) - \text{energy of conformation } c \quad (1)$$

$E(c)$  is:

$$E(c) = -\sum_{i,j=1}^n a_{si} \cdot b_{sj} \quad (2)$$

where:  $a_{si}, b_{sj} = 1$  if  $s_i$  is H aa, and  $a_{si}, b_{sj} = 0$ , otherwise  
and  $a_{si}$  and  $b_{sj}$  are topological neighbors, but are not sequence neighbors

#### 4. Gray Wolf Optimization (GWO) Algorithm

Grey Wolf Optimization (GWO) is one of the newest meta-heuristics proposed by Mirjalili et al, 2014. It is a Swarm Intelligence algorithm which imitate the social hierarchy and hunting behavior of grey wolves.

The grey wolves are divided into four categories: alpha-wolf ( $\alpha$ ) is the highest; beta-wolf ( $\beta$ ) is the second, obedient only to  $\alpha$ -wolf; and delta-wolf ( $\delta$ ) is the third in hierarchy. The others are omega-wolves ( $\omega$ ). During the rush,  $\omega$ -wolves follow the three leaders.

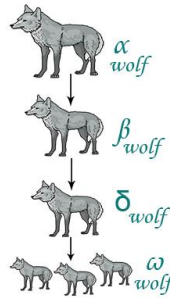


Fig. 1. The social hierarchy of the grey wolves.

The encircling and hunting of the victim can be mathematically formulated by (3)-(6).

$$D = |C \cdot X_p(t) - X(t)| \quad (3)$$

$$X(t+1) = X(t) - A \cdot D \quad (4)$$

$$A = 2a \cdot r_1 - 1 \quad (5)$$

$$C = 2r_2 \quad (6)$$

where the components of  $r_1$  and  $r_2$  are uniform random vectors in  $[0,1]$  and the components of vector  $a$  decrease uniformly from 2 to 0 over iterations.  $X_p$  is the position vector of the prey,  $t$  is the current iteration, and  $X$  represents the position vector of a current grey wolf.

The standard GWO was created to find the optimum of continuous functions.

The prey represents the solution that should be found. As this solution is not known, it is considered that an intermediate position of the first three wolves could be very close to the place of the **prey** (the optimal solution).

Since the optimum position (prey) is not known, the optimization process consists in capturing the prey, which is presumed to find in the positions of the three wolves dominated ( $\alpha$ ,  $\beta$  and  $\delta$ ). Finally, the optimal value is the best position of the  $\alpha$ -wolf.

The equations are:

$$D_\alpha = |C_1 \cdot X_\alpha - X|, \quad D_\beta = |C_2 \cdot X_\beta - X|, \quad D_\delta = |C_3 \cdot X_\delta - X| \quad (7)$$

$$X_1 = X_\alpha - A_1 \cdot D_\alpha, \quad X_2 = X_\beta - A_2 \cdot D_\beta, \quad X_3 = X_\delta - A_3 \cdot D_\delta \quad (8)$$

$$X_{(t+1)} = \frac{X_1 + X_2 + X_3}{3} \quad (9)$$

Advantages of algorithm:

- Few parameters required by the algorithm
- There is no need for mutation or crossover probabilities like Genetic Algorithms.
- It is easier to implement.

The downside is that GWO was created to solve continuous optimization problems. As the Protein Folding Problem is a combinatorial optimization problem, in this situation the GWO cannot be applied in its classical form.

## 5. Gray Wolf Optimization combinatorial (cGWO) Algorithm

In order to be applied the GWO for combinatorial optimization problems, our work consist in adding a crossover type, so that in this way the GWO can be applied to problems that involve discrete or combinatorial functions.

Thus, the modified search operator is replaced with crossover operation. From the GWO algorithm it is retained the idea of going through the entire wolf population that makes crossover with one of three dominant wolves:

$$c_i(t+1) = \begin{cases} \text{crossover}(c_\alpha(t), c_i(t)), & \text{if } rnd < 1/3 \\ \text{crossover}(c_\beta(t), c_i(t)), & \text{elseif } rnd < 2/3 \\ \text{crossover}(c_\delta(t), c_i(t)), & \text{otherwise} \end{cases} \quad (10)$$

where  $c_i(t+1)$  is the conformation resulting from the application of the crossover operator,  $c_i(t)$  is the current wolf of current iteration, and  $c_\alpha(t)$ ,  $c_\beta(t)$ ,  $c_\delta(t)$  is the conformation of the  $\alpha$ -wolf,  $\beta$ -wolf,  $\delta$ -wolf, respectively.  $Rnd$  is a uniform random value between  $[0,1]$ .

In this work, we used single-point crossover. The place, where the string is cut, varies linearly with number of iteration. In the first generations, the location where will be the cutting is close to 1, so that towards the end of the algorithm it reaches close to  $n-1$ , where  $n$  is the length of the protein sequence. Therefore, at the beginning is encouraged exploration, but finally, exploitation. This is because, at first, the resulted conformations from the crossover have big sequences from  $\omega$ -wolves, and to the end, they have a large portions of one of three dominant wolves, which are conformation with high energy.

For example, for a structure by 8 aa, in below image can see how the first half of  $\alpha$ -wolf is concatenate with the second half of the current wolf (an  $\omega$ -wolf). Note that, not all conformations results crossover operation are feasible.

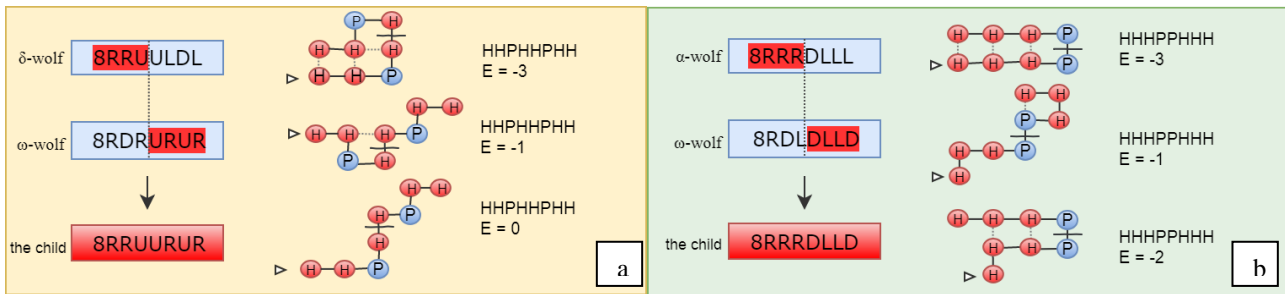


Fig. 2. The crossover operation. (a) the resulting conformation is weaker than parents. (b) the resulting has o intermediate energy. The red is Hydrophobic aa and the blue is Polar aa.

In the above picture it can be seen that after crossover operation it is obtained the following cases:

- the resulting conformation is weaker than the initial conformations. See fig. 2 (a).
- the resulting conformation is better than the initial conformations
- the energy of the resulting has an intermediate value between the energies of the initial conformations. See fig. 2 (b).

## 6. Experiments (Simulation results)

The aim of this paper was to experimentally evaluating in our proposed combinatorial Grey Wolf Optimization algorithm (cGWO). The cGWO was implemented using C# programming language and tested on one standard benchmark HP protein. The parameters of the cGWO algorithm are: number of grey wolf (population size): 10 – 100,000; number of runs for every population size: 10, number of iterations: 1,000.

The sequence tested in this paper is: HPHPPHHPHPPHHPHPPH, a sequence which contains 20 aa. This sequence is well-known structure. It was taken from Unger and Moulton, 1993. In its case, it is known that there are 83,779,155 feasible conformations of which only 4 conformations have the lowest energy level, -9. Note that an optimal conformation is very difficult to achieve. The fraction of the optimal conformations from the total number of conformations is extremely small, only  $4.77 \times 10^{-8}$ .

Below, in table are presented the best result from the 10<sup>th</sup> runs for every population size. It can be observed that our approach has a weak convergence and that the lowest energy was reached in the case of big population size (the cGWO is not able to increase significant the initial solutions). It can also be seen that the minimum energy was obtained in all cases in the first 100 iterations. In the other 900 iterations, is not significant evolution which took place. From this, it can be deduced that the size of the population is more important than the number of iteration. This means that the crossover operator in this form is not the best solution.

In this experiments the  $\alpha$ -wolf it is not conserved from one iteration to another.

Table 1 Results of our proposed cGWO

Population size	Energy from first iteration	Best energy (solution)	No of iteration where the best energy was reached
10	-3	-7	87
50	-4	-6	93
100	-4	-6	68
200	-4	-6	24
500	-5	-8	62
1,000	-6	-8	68
5,000	-8	-9	62
10,000	-7	-9	49
50,000	-7	-9	43
100,000	-8	-9	37

It can be seen that our algorithm is able to obtain the conformations with the best energy. One of the conformation found (energy is -9), is represented in fig below:

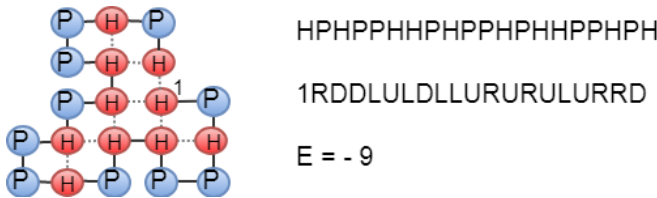


Fig. 3. The best conformation finding the cGWO . The red is Hydrophobic aa and the blue is Polar aa. It can see that H aa forms a hydrophobic core.

In below figure is represented the convergence of cGWO for protein folding on 2D HP lattice for population size = 10,000. In the same picture, it was represented only the first 100 iterations.

Since the first iteration a low energy conformation has been generated (-7). For 42 iterations there was no evolution. In iteration 43, a-wolf reaches the energy -8, so after another six iterations reaches the minimum energy (-9)

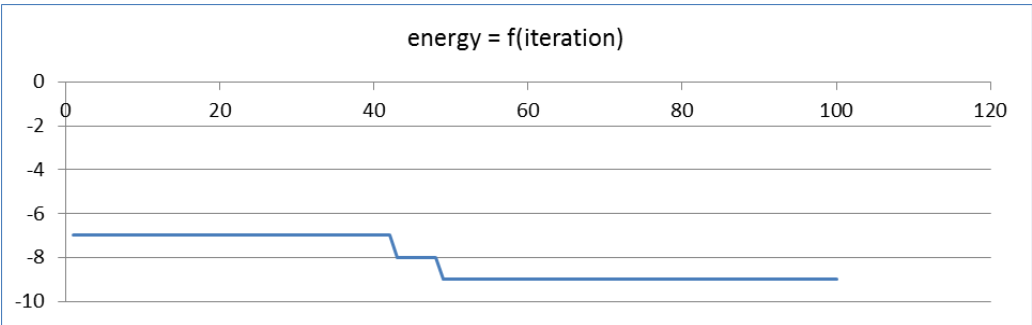


Fig. 4. The convergence of cGWO

## 7. Conclusion and further work

In this work, we proposed a Gray Wolf Optimization Algorithm for solving of protein folding problem on the bi-dimensional Hydrophobic-Polar Model. Due to the fact that the GWO is a meta-euristic for finding the optimum for continuous functions, and protein folding is a combinatorial function, in this paper was presented a modified GWO Algorithm (cGWO) adapted to search for solutions in combinatorial spaces. This includes the crossover, a known evolutionary operator.

This algorithm is simple and shows a good result on the tested sequence on 2D HP lattice model. But the convergence of the algorithm is weak.

The further work will consist in the improvement of our algorithm including mutation and finding ideas for increasing convergence. Then, our research can be extended to other large HP protein sequences and the 3D HP Models.

## References

- Czibula., G., Bocicor, M-I., Czibula, I-G., *An experiment on protein structure prediction using Reinforcement Learning*, Studia Univ. Informatica, LVI (1), pp. 25-34, (2011).
- Dinu, V., Truția E., Popa-Cristea E., Popescu A., *Biochimie medicală – mic tratat*, Ed. Medicală, București, (2006).
- Emary, E., Zawbaa, H.M., Hassanien, A.E., *Binary Grey Wolf Optimization Approaches for Feature Selection*. Neurocomputing. 172, pp. 371-381, (2016).
- Lau K.F., Dill K.A., *A lattice statistical mechanics model of the conformation and sequence space of proteins*, Macromolecules., 22, pp. 3986-3997, (1989).
- Levinthal, C., *How to fold graciously*, Mössbaun Spectroscopy in Biological Systems Proceedings, Univ of Illinois Bulletin, pp. 22-24, (1969).
- Lu, C., Xiao, S., Li, X., Gao, L., *An effective multi-objective discrete grey wolf optimizer for a real-world scheduling problem in welding production*. Advances in Engineering Software 99, 161–176, (2016)
- Madadi, A., Motlagh, M.M., *Optimal control of DC motor using grey wolf optimizer algorithm*. Tech J Eng Appl Sci. 4, pp. 373-379, (2014).
- Mihalaș, Gh-I., Tudor, A., Paralescu, S., *Bioinformatica*, Ed. Victor Babeș, Timișoara, (2011).
- Mirjalili, S., Mirjalili, S.M., Lewis, A., *Grey wolf optimizer*. Advances in Engineering Software, 69, pp. 46–61, (2014).
- Shmygelska, A., Hoos, H.H., *An Improved Ant Colony Optimisation Algorithm for the 2D HP Protein Folding Problem*, In Springer Verlag, editor, In Proceedings of the 16th Canadian Conference on Artificial Intelligence, pp. 400-417, (2003).
- Shmygelska, A., Hoos, H.H., *An ant colony optimisation algorithm for the 2D and 3D hydrophobic polar protein folding problem*, BMC Bioinformatics, 6 (30), (2005).
- Turabieh, H., *A Hybrid Genetic Algorithm for 2D Protein Folding Simulations*, International Journal. of Computer Applications, 139 (3), pp. 38-43, (2016).
- Unger, R., Moulton, J., *Genetic algorithms for protein folding simulations*. Journal of Molecular Biology, 231, pp. 75-81, (1993).
- Yassien, E., Masadeh, R., Alzaqebah, A., Shaheen, A., *Grey Wolf Optimization Applied to the 0/1 Knapsack Problem*. International Journal of Computer Applications, 169, pp.11-15, (2017).
- Zhou, C., Hou, C., Zhang Q., Wei, X., *Enhanced hybrid search algorithm for protein structure prediction using the 3D-HP lattice model*, J of Molecular Modeling, 19 (9), pp 3883–3891, (2013).

## Using film to interpret literature: Charles Dickens’ “A Christmas Carol”

Esther Andraș<sup>a\*</sup>

<sup>a</sup> Colegiul Tehnic “Dimitrie Leonida” Petroșani, Department of Foreign Languages, str. 22 Decembrie, nr. 6, Petroșani, 332020

---

### Abstract

It is argued within this paper that film is becoming an important educational tool in the English classroom, that it enlivens and enriches classes and it facilitates students' understanding of course materials. Although students may still treat film chiefly as passive entertainment, with the appropriate teaching methods and strategies they can become sophisticated interpreters of the interplay of sound and image. Film should not be regarded as a guilty pleasure or the "reward" at the end of the semester but a legitimate means of enhancing literacy.

*Keywords:* Dickens, A Christmas Carol, literature, film, technology

---

### 1. Introduction

The development of technology and the rise of digital revolution have changed language teachers' perception on promoting the students' English proficiency. The way in which teachers can stimulate the language development of their students is by providing what is known as an acquisition-rich classroom. Foreign language teachers are intrigued to discover the effectiveness of a “different” teaching and learning environment that is supported by multimedia technologies. The main focus of this paper resides in the teaching of literature with innovative methods and multimedia resources. It is a venture that enables teachers who have little or no experience of the use of multimedia to benefit from its numerous virtues. Teaching literature with technology aims to encourage students to think creatively and independently, to appreciate not only the stimulation but also the enjoyment derived from the study of literature.

Authentic films should not be considered additional resources in a literature class; on the contrary, this type of content ought to be integrated in the curriculum. The acquisition of receptive skills becomes a vital prerequisite of good productive abilities. Movies provide exposure to the real language uttered in authentic settings and the culture in which the foreign language is spoken (Stempleski, 1992, Telatnik and Kruse, 1982). Selecting the appropriate literary text – “A Christmas Carol” by Charles Dickens, animated by the video production, may encourage students to achieve a new kind of confidence in reading and overcome their sense of insecurity, experiencing the feeling of success. The modern method of teaching literature is learner-centred, focusing on the student's response and creativity.

A further aim of this study is to explore to what extent films can assist students to engage in interactive activities that offer opportunities to read, to write, to listen to, to watch and to discuss oral and written English texts expressed in a variety of ways. Technology also represents an escape from the rigid learning patterns encountered in the traditional settings. The use of technology has assisted for many years with the goal of reaching students. Multimedia addresses various learning styles typically neglected by traditional teaching methods, positively impacting on the learning experience. The numerous and extensive opportunities for natural communication provided by multimedia allow for the complete integration of language skills. Furthermore, research on second language acquisition suggests that more efficient learning takes place when students are engaged in relevant tasks within a dynamic learning environment rather than in traditional teacher-led classes. Working successfully in groups fosters the development of transferable skills, enhancing social skills and interaction. Dickens' work is a landmark in the comic literature of the world. His genius has created an enormous variety of eccentric and highly colourful characters described with a vividness which gives the stamp of his fictional art. The poetic structure of his novels, the descriptions of places charged with a high symbolic

---

\* Corresponding author. Tel.: +40-733974126

E-mail address: esther\_peter2004@yahoo.com

meaning point to Dickens' allegiance to the great Romantics of world literature. The reader is convinced through rhetorical devices which rely on the effect of laughter, suspense, sympathy and pathos. One reason for the great popularity which he enjoyed at the time when he wrote his novels was the fact that Charles Dickens identified himself with the public and shared common experience with it. He performed public readings from his novels in England and America which established an even closer intimacy between himself and the readers. Besides, in his youth, Dickens had wanted to become an actor and one of his hobbies was to act in plays with amateur actors. This theatrical inclination influenced the nature of his fiction. Because of its specific dynamism, its evocative quality and strong visual appeal, his fiction could be acted.

"A Christmas Carol" is one of the most popular stories in English literature. With its numerous literary, stage, radio and film adaptations, the tale has become a holiday classic and the character, Ebenezer Scrooge, has become a cultural icon. Each year during the Christmas season, this famous story is revived once again, teaching life lessons and morals. It is interesting to note that, rather than chapters, Charles Dickens has divided his novella into five staves. Staves are normally associated with music, dividing the music into verses, much like a poem. Dickens has done this in order to give his story a lyrical feel, providing him with another opportunity to create sentiment and emotion. Holiday tradition gives people a sense of comfort and purpose. Perhaps Dickens chose Christmas time as the time frame for his story because he truly believed in the power of Christmas to unite fellow men. Revisiting "A Christmas Carol" by Charles Dickens seems like a good practice as the story is timeless and appropriate for all age levels. It teaches students to look past the moment to see what their actions will reap, and illustrates essential morals like compassion, kindness, generosity. The novella encourages self-direction by teaching students how to use their feelings and sense of responsibility to decide whether something is right or wrong and decide on the course of action. It creates several hypothetical circumstances which allow students to assess their feelings and choices as a chance to reinforce their values. It also demonstrates how English literature can be used to teach character education. Character education is a vital aspect of students' learning because it teaches them different social and moral lessons with impact on their future development.

As written texts, the classics are often inaccessible to students. The setting and historical background can prove challenging, the complex language can interfere with fluent reading and complete understanding of the text. Using film is a way to ensure comprehension, whether with the whole filmed version of the story or fragments that complement the themes, characters, setting or plot of the story. Like the words in a novel, everything students see and hear on screen contributes to the overall meaning. A critical viewer can predict, make connections, infer, ask questions and interpret. In both written texts and films, meaning is made through the details of character, theme, plot, mood and symbols. It is the teacher's task to act as organizer and guide students to become active interpreters. Nearly all the works of classic literature students study in high school have been adapted for film, some of them in multiple versions. The major difference between the film and the book is that visual images stimulate our perceptions directly, while written words perform this indirectly.

Film is a more direct sensory experience than reading and adds colour, movement and sound. But the film is also limited. Whereas there are no time restrictions on a novel, the film must compress events into approximately two hours. Film does not offer the same amount of freedom a novel does - to imagine the characters, the setting and the plot. And, above all, the filmmakers adapt a literary work to film using their own vision and tools, thus altering the original spirit of the story. It is also a common practice for filmmakers to make changes in order to emphasise traits of character or add explanations. Substitutions of language can be made to be recognizable to a modern audience. To what extent can a film be "faithful" to a work of literature? Is the film intended to capture the novel literally or to capture its spirit?

There have been more than fifty adaptations of Charles Dickens' "A Christmas Carol" for movies and television. In 1908 a fifteen-minute silent film production of Dickens' story, in 1938 MGM presented "A Christmas Carol" starring Lionel Barrymore. The 1999 film version of the novel, starring Patrick Stewart as the famous Scrooge, is considered one of the most convincing and faithful to Dickens' story. Patrick Stewart is a classically-trained actor and thus is perfect for a literary character like Ebenezer Scrooge. This adaptation has all the qualities of a very well-done period costume drama. The script is practically a scene by scene transcription of the novella to screen. No scenes are missing and very few are added. It represents an appropriate version for use in an English literature class as it is probably the most accurate representation.

Although setting is often taken for granted by viewers, there is a great deal of work behind the creation of sets, costumes and makeup which remain faithful to the description in the narration. A filmmaker's use of setting reveals important aspects of the people and the society the story depicts. It can include social, cultural, political and historical aspects (the details of everyday existence, work, class, gender, politics, customs) that define a time and a place (for example, Victorian England). The setting of a film can emphasise the symbolic role of a place or highlight themes and ideas. Establishing shots often go unnoticed by viewers but are key elements of the plot. It is interesting to note how the filmmakers portray the grounds and house in Dickens' novels.

Simple things like a close-up of the actor's face or camera angles can express a character's feelings and personality. Elements such as a character's age, dress, speech, facial expression can also influence the viewers' understanding. The music playing in the background or a darkened light on the actor's face enhances the students' perception of a character. Also the choice of costumes can provide more information than we are aware of.



Film and literature have their own tools for organizing narrative structure. In a novel, a new chapter might take the reader back to a different time and place in the narrative whereas in films the director can make use of flashbacks or a crosscut. Even sounds can substitute a narrative sequence in a novel. Films reveal theme in extremely subtle ways and everything from the lighting to the makeup must enhance it. Directors try to find images to represent metaphors for a theme, usually something visual and dramatic that conveys the overall message. When an image or sound is repeated, it becomes a motif or symbol in the film, reminding the viewer of an important idea. The opening scenes in both film and literature announce the theme to be established. In film, point of view can change rapidly. Multiple techniques have been invented to inform the viewer when the point of view changes. Besides the eye-line match, there are techniques such as the voice-over, the flashback, slow motion, distorting lenses and even special sound effects to tell us we are in a character's imagination, not reality. The camera might show a character at first, then move to another, intercept looks and reactions, then feature a new character in the film. A combination of music, lighting and camera angles can create the tone and mood employed by the author of the novel. The director can manipulate the viewer's emotions by generating suspense and obtaining sympathy and pathos. In Dickens' novels tragedy and comedy constantly play off each other and the elements of filmmaking work together to illustrate the author's attitude towards the characters and events. The use of specific colours carries a symbolic message and deliberately enhances the mood.

## **2. From viewing to producing video**

In the following section I aim to explore how bringing new technology into foreign language classes can activate students and determine them to interact and cooperate. The focus is on digital video devices and current approaches to video production as tools for language learning.

Nowadays most teachers integrate the communicative approach within their teaching and regard communication as the main goal of the lesson. The use of video enables students to observe interaction in an authentic setting. Moreover learners have the unique opportunity to witness different gestures and other paralinguistic features of languages which add further meaning to the text. Many language methodologists argue that most video-watching activities aim at the form and structure of the target language and less on meaning. They must also be considered passive as they do not generate communication and thus watching video becomes time consuming and non-motivational.

Watching a video can be successfully turned into a video production project in which communication will facilitate language acquisition. Today digital technology encourages teachers to produce and edit video in a classroom setting. The new generation of students can perhaps fulfil the task of simplifying the production process. Much of the technology already exists on the students' computers, even mobile phones and tablets and editing software can be downloaded for free on the Internet. Enabling students to work with video production is considered a beneficial tool that makes use of both the target language and the new technology. It is suggested that video productions be created as part of an optional course or project as it is impossible to involve the class as a whole. It is often better to divide the class into groups and assign different types of tasks regarding research, script work, and technical issues. The preparatory work should include techniques and activities that enable the entire group to participate in the planning of the video.

An essential part of video production refers to script developing. In this context the teacher plays the part of getting the students started by supplying ideas, speech patterns and examples. The language level of the script should be appropriate for the students' age and linguistic abilities. It is a new experience to use video production as a teaching aid with literary works. After having studied a novel or a play, the students can display or reinforce the acquired critical and analytical skills through a video-producing activity. At this point they should decide how they can portray the content of the literary text using video. As the length of the recorded material will be obviously reduced as compared to the book or the adapted film, it is of great importance to guide students through the script writing stage. A relevant choice of dialogues will ensure the meaning and message of the short film.

Also during the preparatory stage, it is important to decide on the location of the recording, the actors in front of the camera and the students behind the camera who sustain the technical process. Having established the role of each member of the production group, it is high time for the "actors" to start rehearsals. Students are required to learn their lines by heart and follow the instructions in the script when displaying attitudes and feelings. This is a unique opportunity to portray characters and illustrate the tone and style of the production. Once the equipment is prepared and checked, the recording proceedings may begin. Digital video technology makes it very easy to record a large number of sequences without the challenges of a real scale studio. It is a good idea to try to reduce mistakes when recording otherwise the editing process will prove long and discouraging. The next stage implies editing the recorder material by importing it to a computer. There are editing programmes such as Microsoft Movie Maker, Virtual Dub, WAX, which can be downloaded for free. These programmes allow users to remove dissatisfying scenes and work only with the best recordings. Music or pictures can be added into the video, titles, notes, visual and sound effects. The final product should appear in a compressed format such as divx, mpeg, avi, mkv etc.

Having completed the video production it is essential to present it to the students so that they may reflect on various aspects: performance, use of language, pronunciation, diction, accurate illustration of plot, theme and characters. This post-task activity will enable students to assess critically their own work and improve it in the future. The teacher plays the key role in language teaching. Traditionally the main task of the teacher was to transmit information and check students acquired knowledge. Today the role of the teacher has dramatically changed. A teacher in the technology era

must go beyond knowledge transmission. Along with the development and implementation of new technology in the classroom, a new dimension is added to the role of the teacher, that of facilitator and manager. It is the teacher who can add the power to videos and create a successful learning environment. As Loneragan (1995) states, the use of videos is not to “replace, rival or overshadow the teacher” but to ensure fruitful language acquisition. This type of multidimensional environment is student-centred, very active and requires careful planning and students’ cooperation.

Within the classroom one of the most important roles that teachers have to assume is that of organising students to do various activities. This involves presenting the information, explaining clearly the activities students are expected to perform, dividing them into pairs or groups, offering feedback when the lesson has come to an end. J. Harmer (2001:59) summarises the teacher’s role of organiser as follows: engage > instruct (demonstrate) > initiate > organise feedback. Often students find themselves unable to fulfil the required tasks, they become confused or are unable to proceed for lack of vocabulary. In such situations the teacher should act as a “prompter” and help students in a discreet and encouraging manner by offering suggestions, words, ideas. Students may also need information during an activity and turn to their teacher as the most available and helpful resource. When acting as resource it is difficult to prevent students from becoming over reliant on their teacher. Offering guidance as to where to look for information could encourage students to use resource material for themselves and become more independent learners.

### 3. Conclusions

This paper has presented and discussed the use of multimedia in a learning environment to facilitate the successful study of literature, to equip students with creative and critical thinking skills and to enable them to experience technology-supported learning situations.

As evidenced by this study, movie videos can be an invaluable teaching tool in literature classes if teachers can incorporate their use in effective pedagogy. The teacher plays the key role in language and literature teaching by creating a successful learning environment. The teacher acts as organizer and initiates the activities, provides instructions, clarifies questions, leads the transitions from one activity to another, stops the activity and gives proper feedback. Many students who are uninspired by the traditional methods of teaching are motivated and stimulated by the vivid images, appealing videos, the rich and contextualized language. As a result, the efficient acquisition of receptive skills generates comprehensible learner output.

### References

- Dal, Michael. (2010). *Digital video production and task based language learning*.
- Erben, T., Ban, R. & Castaneda, M. (2009). *Teaching English Language Learners through Technology*. New York: Routledge
- Intajuck, Yongyut. (2006). *Maximizing the Utilization of Video in the EFL/ESL Classroom*. Uttaradit, Thailand.
- Keene, M.D. (2006). *Viewing Video and DVD in the EFL Classroom*. Bunkyo Gakuin University Journal, Vol.8 (1), 217-234 (217-234).
- Kusumarasdyati. (2004). *Listening, Viewing and Imagination: Movies in EFL Classes*. Vancouver: 2nd International Conference on Imagination and Education - Vancouver, Canada, July 14 - 17, 2004.
- Kusumarasdyati. (2006). *The Use of Movie Videos to Enhance Cross-cultural Understanding*. Wollongong: The 16th Biennial Conference of the Asian Studies Association of Australia, 26 June - 29 June 2006.
- Lin, Li-yun. (2009). *DVD Films for Improving Freshman English Learning*. Taipei, Taiwan: Hwa Kang Journal of English Language & Literature, H. 15, (203-215).
- Schulten, Katherine. (2011). *Film in the Classroom: A Masterpiece Guide for Teachers, Revised Edition*. Boston: the Educational Outreach Department of the WGBH Educational Foundation.
- Sherman, Jane. (2003). *Using Authentic Video in the Language Classroom*. Cambridge, UK: Cambridge University Press.
- Stempleski, S., Tomalin, B. (1990). *Video in Action, Recipes for Using Video in Language Teaching*. Upper Saddle River, NJ: Prentice Hall International.
- Wong, M., Noronha, M., & Chaplin, V. (2007). *The Use of New Media Technological Aids in the Language Classroom: Video and Internet*. Macau: 1st International Conference of English Discourse and Intercultural Communication.

## Sport - An inexpensive way of treatment for poor people

Laura Marica<sup>a</sup>, Cristian Siminic Ilioni<sup>a</sup>

<sup>a</sup> University of Petrosani, Department of Social and Human Sciences, str. Universității 20, Petroșani, 332006

---

### Abstract

Inactivity is described by the Department of Health as a “silent killer”. Evidence is emerging that sedentary behaviour, such as sitting or lying down for long periods, is bad for your health. I say this because even poor people have come to have in the priority list TV and computer. Many parents who live with bad neighbors do not let their children play outside for fear that something bad might happen to their children and therefore prefer to keep them in the house where they sit and watch TV or play on the computer. This makes them sick mind and body.

*Keywords:* Sport, people, priority, poverty, statistics;

---

### 1. Introduction

Thinking about it, sometimes compassionate, sometimes just watch them and try to discern their intimate mechanisms of functioning, their inner dynamics that make them to be so petty, limited, partly naked, unable to receive and even less to give.

“Previous generations were active more naturally through work and manual labour, but today we have to find ways of integrating activity into our daily lives,” says Dr Cavill .

They are poor people. I do not care for their money and no matter how many materials have checked on the priority of my list, I'm just curious how many acres lies in their heart and how tall they ideals fly ?

### 2. What does poverty mean ?

- Poverty is about struggling to meet basic necessities such as food, shelter and clothing;
- It also means not being able to access the following to ensure a comfortable quality of life;
- Essential goods and services;
- Meaningful employment and decent earnings;
- Adequate and affordable housing;
- Safe neighbourhoods with public amenities;
- Health and well-being;
- Social networks;
- Basic human rights.

### 3. Exactly how “poor” do you have to be to be poor ?

- Statistics can suggest aspects of poverty - such as, income levels, educational attainmen, or employment;
- From these numbers, an assumption about quality of life may be made;
- But statistics do not reflect the *experience of living in poverty*;
- To look deeper at the issue of poverty, one may consider two important issues.

### 4. Depth of Poverty and Populations Affected by Poverty

Poverty is experienced differently by different people. Even though one may be employed full-time, they may still experience poverty. Poverty is experienced differently by:

Those at-risk of poverty – people who are one or two pay dets away from poverty or whose employment is insecure;

The working (waged) poor – people working close to minimum wage and trying to make ends meet

The temporarily unemployed – individuals facing short-turn employment due to layoffs or other reasons

The persistently unemployed – people who face barriers in finding and maintaining employment

The dependent – individuals on a fixed income (i.e. retired people, people with work limiting disabilities)  
The homeless – people living without proper housing.



Fig. 1. Poor people

First i should tell you that many people consider poverty as a disease. Why? The poor peoples lifestyle leads to increased stress levels and the stress of not having anything can reflect on the human body.

No matter how much you want to help these people closed in themselves, living only from day to day, without caring what leave behind, which teaches pass those who are supposed to help them get out of this miserable situation in which they are, poverty.

I started thinking that if we want to help these people we need to focus our attention in order to teach their children not to be like them.



Fig. 2. Very poor children

For children, stress that they live in some dirty house, eat very little and unhealthy living around some parents who are stressed as well and they are uninterested in what happens to their children, of some neighbors with the same level of poverty, affects both mentally and physically.

Although are very poor, I noticed that most of them smokes a lot, and drowns his sorrows in several glasses of drink and that makes them aggressive with their families and unfortunately their children who grow up in such environments do nothing but use the same behavior, they are not integrate into society and become addicted to alcohol and drugs.

All this leads to many health problems, which due to lack of money and education not solve them, reaching the death rate increases significantly.

Stress can lower the potential to focus on teaching, the behavior change.

By including children in sports activities in schools or sports clubs, decrease the level of illness because of the environment in which they live, reduce stress, and increase their adaptation to their social environment and the opportunity to develop physical harmony.

Returning to the factors that influence poor human health, they are very numerous: from misery to poor eating habits, stress of being poor, cold winter and so on, all these factors affect both the human psyche and the muscular system, articular, nervous, circulatory, cardiovascular, etc.

### **5. Study on practicing physical exercise by people with health problems**

Studies show that only 10% of the population is sport frequently, which means that the remaining 90% are ideal candidates of heart disease.

In some studies the results show that in patients with heart problems and prediabetes both physical and medications reduce the risk of death. Among patients who have suffered an accident stroke, physical activity appears to be more efficient than drug therapy.



Fig.3. Those poor children

Regular physical activity using large muscle groups, such as walking, running, or swimming, produces cardiovascular adaptations that increase exercise capacity, endurance, and skeletal muscle strength. Habitual physical activity also prevents the development of coronary artery disease (CAD) and reduces symptoms in patients with established cardiovascular disease. There is also evidence that exercise reduces the risk of other chronic diseases, including type 2 diabetes, osteoporosis, obesity, depression, and cancer of the breast and colon.

This American Heart Association (AHA) Scientific Statement for health professionals summarizes the evidence for the benefits of physical activity in the prevention and treatment of cardiovascular disease, provides suggestions to healthcare professionals for implementing physical activity programs for their patients, and identifies areas for future investigation. This statement focuses on aerobic physical activity and does not directly evaluate resistance exercises, such as weight lifting, because most of the research linking physical activity and cardiovascular disease has evaluated aerobic activity. Whenever possible, the writing group has cited summary articles or meta-analyses to support conclusions and recommendations. This evidence supports the recommendation from the Centers for Disease Control and Prevention (CDC) and the American College of Sports Medicine (ACSM) that individuals should engage in 30 minutes or more of moderate-intensity physical activity on most (preferably all) days of the week.

Let's talk about depression. In Romania, people suffering from depression rises to the top limit of the European Community, that means over 3 million Romanian – that means 15% of the population of the country.

Since the early twentieth century until today have done hundreds of studies demonstrating the immense benefits to the mental health of regular exercise. The results of research, which involved hundreds of thousands of people cannot be challenged by any member of the scientific community, therefore it is and prefer keeping silence about this therapy in medical protocols taught in medical schools. So, as the area moves a lot of money, enough to be purchased research institutes, politicians and psychiatrists, the world suffer and suffer increasingly more diverse mental disorders, although the improvement and even cure can be so close. Research proves the positive effects of exercise for most mental disorders: anxiety, depression, panic, schizophrenia, Alzheimer's dementia, etc.

In recent years, studies have focused on the benefits of exercise on mental and emotional health. Both youth and adults who practice exercise regularly have better mental and emotional health compared with the inactive, sedentary and "exercise reduces symptoms of depression and anxiety and improves disposition " (World Health Organization-WHO).

Therefore, WHO recommends exercise as a way of reducing the risk of depression or anxiety. Lifestyle changes and, in particular, the practice of regular physical exercise has become an alternative or complementary intervention as psychotherapy and drug therapy.

## 6. Conclusions

Physical exercise is an effective way of regulating or controlling the negative emotional states (depression, anger, anxiety, worry); improves quality of sleep; reduce the tension, fatigue and negative impact of daily stress.

Planned involvement in physical activity also increases the frequency of social interactions which has as consequences that strengthening social support and increase the positive feedback received. The consequence of this is to improve wellness and reduce anxieties or depression.

Although poor some people are more open to learn what is right and accept some advice, which often lead to changing conceptions of life.

If exercise were a pill, it would be one of the most cost-effective drugs ever invented," says Dr Nick Cavill, a health promotion consultant.

Research shows that physical activity can also boost self-esteem, mood, sleep quality and energy, as well as reducing your risk of stress, depression, dementia and Alzheimer's disease.

People are less active nowadays, partly because technology has made our lives easier. We drive cars or take public transport. Machines wash our clothes. We entertain ourselves in front of a TV or computer screen. Fewer people are doing manual work, and most of us have jobs that involve little physical effort. Work, house chores, shopping and other necessary activities are far less demanding than for previous generations.

We move around less and burn off less energy than people used to. Research suggests that many adults spend more than seven hours a day sitting down, at work, on transport or in their leisure time. People aged over 65 spend 10 hours or more each day sitting or lying down, making them the most sedentary age group.

## References

- Biddle, S. J. H., Sallis, J. et al. (2001), *Young people and health-enhancing physical activity: Evidence and implications*. London: Health Education Authority
- Bota, A., (2006), *Exerciții fizice pentru viață activă – activități motrice de timp liber*, Editura Cartea Universitară, București
- Baciu, M. (2009), *Sportul și calitatea vieții*, Edit. Napoca Star, Cluj-Napoca;
- Bălașa, A. (2007), „Sănătatea, componentă esențială a calității vieții”, Rev. Calitatea Vieții XVIII, nr. 2.
- Băltășescu, S. (2000), „Modele de percepție a calității vieții”, în Rev. Calitatea Vieții XVIII, nr.11.
- Derevenco, P., Anghel, I., (1992) *Stresul în sănătate și boală. De la teorie la boală*, Ed. Dacia, Cluj-Napoca
- Dragnea A., (2002), *Sociologia sportului*, Ed. I.E.F.S., București
- Dumitru, Gh., (2007), *Sănătate prin sport pe înțelesul fiecăruia*, Ed. Sportul pentru toți, București 68.
- Dumitru, Gh., (2008), *Ghid pentru sănătate și condiție fizică*, FRSP, București
- Eilmore J, Costill D. *Physiology of sport and Exercise*. Human Kinetics Champaign, 1994.