

**MINISTRY OF EDUCATION
UNIVERSITY OF PETROȘANI
MINING FACULTY
DOCTORAL SCHOOL
DOCTORAL FIELD: INDUSTRIAL ENGINEERING**



Eng. Florin – Ionel BURDEA

THESIS

**Scientific supervisor
Professor, Ph. D. Habil. Eng. MORARU ROLAND IOSIF**

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**Optimization of the major risk management system
specific to critical infrastructures in the field of civil
explosives**

SUMMARY

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1. Research context and motivation. The topicality, the necessity and the importance of the topic

This doctoral thesis is the result of a scientific research project designed and conducted based on the author's experience, bibliographic studies, theoretical and applied research carried out during the doctoral internship. The approach to the research topic reflects the author's affinity for the operational environment and "industrial security", his constant concern for adapting to changes that generate various problems that occur at a fast pace and are often solved by multidisciplinary technical solutions. The normative-legislative compliance imposed by the rhythm in which the technical and organizational procedures are carried out in the industrial units, due to the uniqueness of the competences of the human factor and the mode of action of the hazardous flows. The long practical experience in the field of occupational safety and health in various organizations with presumed high risk, the author's interaction with exceptional specialists in technical and managerial fields, cultivated the technical-applied intelligence of creative and constructive type of the thesis author, giving him the ability to understand that "potential dangers" require the use of systemic, systematic and flexible approaches.

From the perspective of the doctoral program, the approach to the research topic is a multidisciplinary approach that involved combining knowledge, managerial knowledge (own experience) in the field of occupational health and safety (OSH) at the organizational level, with new approaches and concerns about major accidents. in which dangerous substances are involved.

Major accidents involving hazardous substances pose a serious threat to both humans and the environment. Moreover, these accidents lead to substantial economic losses and negatively affect sustainable economic growth. However, the use of hazardous substances is inevitable in some industrial sectors that are essential for a modern, industrialized society. To minimize the associated risks, major-accident prevention measures are needed to ensure an adequate level of preparedness and response in the event of such accidents. In many countries, the previous century was one based on a strong development of industrial activity. From a historical perspective, the industrial areas have been located outside the localities, in areas with low population density. This way of developing the industrial activity can be considered at the moment as obsolete, due to the acceleration of the urbanization process, due to the interest of the population to approach the areas of economic interest. The location of the industrial sites in the immediate vicinity of the areas likely to be affected by a possible accident has caused a significant increase in the level of technological risk.

Safety professionals are increasingly interested in quantitative risk assessment and understand that no professional activity, including those involving explosives, is risk-free. The simple quantitative risk assessment does not eliminate the risk of events caused by activities involving explosives, and tools are needed to ensure the application of a management system as efficient as possible, which ensures both the assessment of the level of risk in the activities carried out and the measures which must be taken to eliminate, reduce both the risks and the consequences of possible events.

As a result of industrial accidents with particularly serious consequences, which have marked public opinion, decision-makers in the European Union have adopted and continuously developed the legislative framework on the control of major-accident hazards involving dangerous substances. . This control is achieved by creating a set of prevention and protection measures adopted in order to limit the likelihood of a major accident and reduce the severity of the consequences on a site. The Seveso Directives explicitly provide for the obligation of operators to identify and quantify the risks of a major accident, emphasizing imperatively their obligation to take into account the environment likely to be affected by the occurrence of such an accident.

The purpose of an effective safety management system is both to implement the legal requirements for the prevention of major accidents, but also to succeed, if such accidents occur, through the actions taken, minimizing their impact and magnitude. The major accident prevention policy must be compatible and integrated with the general policy of the organization but also with the policies of other branches of management, such as quality or environmental management. This policy must be based on the principles of preventive action and the concept of sustainable development so that technical security measures are also economically feasible, but also prevent and limit the possible negative consequences of the use of hazardous substances, both on the health of the population but also on the environment. According to the definition, "major accident" means "an adverse phenomenon, such as major emissions, fire or explosion, resulting from uncontrolled events during the operation of an objective covered by the presence of the Directive and which seriously endangers human health and / or the or late, inside or outside the target, involving one or more hazardous substances ". Thus, at present, it is more and more admitted and recognized that the vast majority of industrial accidents have as a fundamental cause the faulty way in which the management is carried out at the level of economic operators.

For the prevention of industrial accidents at source, it is particularly important that this type of measure is part of the company's policy. In this sense, this prevention policy must be more than a simple statement of intent of the management at the highest level (top management). The company must ensure that the policy is implemented and that a high level of protection is ensured by implementing all necessary measures (not only technical, but also those concerning the organizational structure and management of the company) to achieve this objective. Risk assessment is a structured procedure for the qualitative and / or quantitative assessment of the level of risk generated by hazard sources identified in installations. The purpose of the risk assessment is to provide the information needed to make a decision.

It is increasingly recommended that the processes of identification, assessment and control of risks be carried out mainly proactively rather than reactively. The implementation of technical means of protection may increase the costs, if these means are implemented after the completion of the design of a storage site or after its construction. In general, changes made at the design stage are less costly and more efficient than those made later, which fully justifies the start of the risk analysis and assessment process at this stage.

The need and importance of optimizing the management of major risk specific to critical infrastructures in the field of explosives for civil use, resides for the following reasons:

- i. major accidents on an industrial site are explosions, fires and emissions of toxic substances. The consequences of such accidents can be serious, even catastrophic, they generally materialize in human losses, the "ecological" damage to the natural environment and damage to property;
- ii. risk quantification involves identifying the potential for failure of the various components of the system, which can be achieved by constructing accident sequences in the systems in which explosives are used or stored. This approach can be used to support competent authorities in assessing the relative level of safety and to highlight the importance of introducing additional safety measures in industrial facilities and sites where explosives are used and which are subject to the Seveso Directive;
- iii. the analyzed system must be examined starting from the initiating events to determine which of these possible initiating events are also physically possible. For each of these initiating events, in order to increase the level of safety and security, additional safety measures and / or support measures have been identified that can be introduced in the system. For each accident sequence, the safety measures that may or may not be introduced in the system to be analyzed have been ranked, thus providing a system of trees specific to the accident sequences;

- iv. the methodology of analysis, assessment and classification of major accident hazards (explosion) in the case of explosives depots, allows the quantification of possible effects on neighborhoods and human health, including the delimitation of emergency planning areas ;
- v. the criteria have been established for the elaboration of a specialized computer application that can be an analysis tool from the design phase of a warehouse, but also a tool that can be used to quickly identify the existing risks on a site and the measures security measures that can / should be implemented;
- vi. you. the use of a specialized application by the institutions responsible for the authorization of explosives depots would allow a much more applied analysis of the security level of the site. This practical analysis allows the authorization of economic agents with activity in the field to be made on the basis of the real and concrete situation, given that, at present, this authorization is based mainly on fairly general documents, without allowing an analysis. detailed security requirements that should be met for the safe operation of a warehouse;
- vii. are you coming. the use of a computer application in the field of explosion risk management at explosives depots for civil use allows to ensure the necessary premises for the elaboration, in objective and specific conditions, of the necessary documents for these types of technical infrastructures, from their design phase and quantification of the degree of damage to the analyzed locations but also to the areas that are located in their vicinity;
- viii. the computer application is a viable solution to solve the problems in the field of major risks specific to technical infrastructure for storage of explosives, which can help perform a quick analysis of the site, to impose conditions prior to construction of the objective in its design phase;
- ix. the results provided by the application can bring important and real benefits to economic operators who have technical infrastructures for the storage of explosives for civilian use. The results of the application analysis can be used as a basis for choosing policies, procedures and operations at such industrial sites and issuing recommendations to achieve pre-established performance levels in the area of total security.

The arguments presented above support and emphasize the importance, necessity and opportunity of scientific research dedicated to optimizing the management of major risk specific to critical infrastructures in the field of explosives for civil use, the results of which can be used by those involved in this activity.

2. Objectives of doctoral research

The **general objective (GO)** of the doctoral research was to define a methodological approach and specific application tools to identify, formalize and structure the applicable security requirements for reducing or eliminating risks in explosive storage sites. The intended result consists in the elaboration and integration of more or less formalized tools, including in the form of a specialized computer application, applicable by specialists working in the field of conception / design and use of explosives depots, in particular, but also in general. users of hazardous substances depots. In general, the principles established by this paper are also valid for other hazardous substances, in order to minimize the major risks associated with the operation of this category of industrial sites, through their individual, comparative and applicative analysis.

In order to achieve the general objective mentioned above, the following specific objectives have been set:

SO 1. Carrying out a documentary study aiming at the evolution of the regulatory legislative framework regarding the control over the major accident hazards in which dangerous substances are involved;

SO 2. Research on the current state of the conceptual and methodological framework for addressing critical infrastructures in the field of explosives for civilian use and expand the study by

developing a synthesis on explosives for civilian use, starting from their definition, continuing with legislative aspects on storage, transport and use of explosives, technical - theoretical notions regarding the composition, characteristics and classification of explosives for civil use;

SO 3. Carrying out a documentary study on the current state of knowledge in the field of quantitative analysis of the risk associated with explosives deposits, based on the literature and studies conducted over time in this regard;

SO 4. Event Tree Analysis (SEA), focusing on how the results of this analysis can be used to take additional security measures, correlated with the analysis of all possible occurrences of the initiating events that could lead to a potential explosion ;

SO 5. Analysis of the security measures that could be adopted, by installing technical security barriers or by applying other measures of an organizational or other nature, so as to aim at preventing any possibility of occurrence of the already identified initiating event, and delimitation of accidental sequences, consisting of an initiating event, failures or specific successes of the functionality of protection measures, their grouping into classes (branches of the event tree) in which the sequences in a branch result in the same consequences;

SO 6. Elaboration of the methodology for analysis, assessment and classification of major accident hazards (explosion) in the case of explosive depots, quantification of possible effects on neighborhoods and human health and methodology for delimitation of emergency planning areas;

SO 7. Substantiation, development / elaboration and validation of a specialized computer application for the explosion risk management system specific to the critical infrastructures in the field of explosives for civil use.

3. The logic of research development and the brief description of the structure and content of the thesis

3.1. Research development logic

Figure I.1. presents in a structured way the block scheme related to the development logic of the research materialized in the doctoral thesis, in accordance with the specific objectives defined in the previous paragraph. Without being an operational scheme, the graphic representation has the role of highlighting the coherence of the studies undertaken in stages, with the gradual taking into account of the partial results obtained after each of the phases.

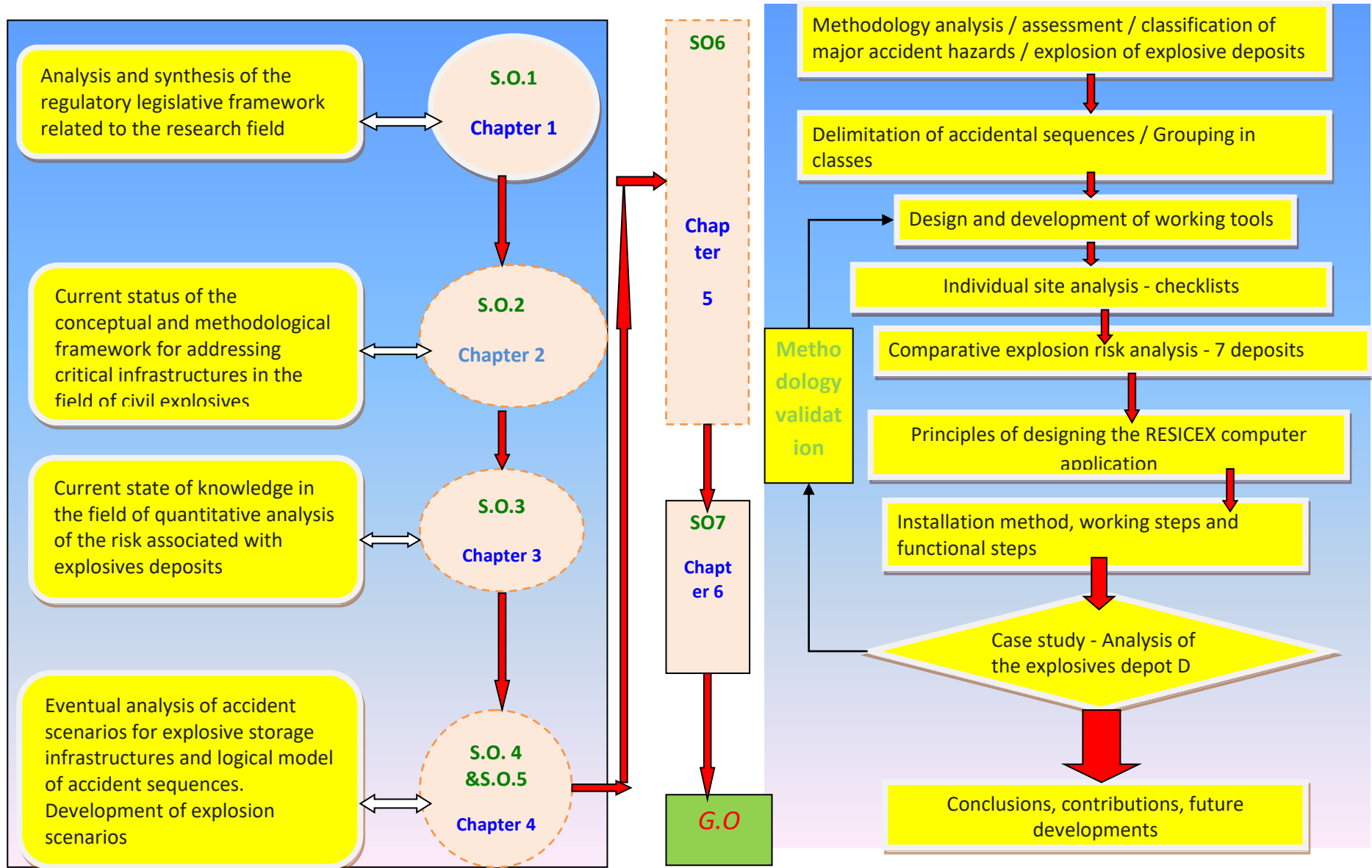


Fig.I.1. Logical scheme for carrying out the stages of doctoral research, in correlation with the specific pre-established objective

3.2. The structure of the doctoral thesis

The doctoral thesis is structured on 7 chapters and includes 129 pages dedicated to the scientific approach itself and 82 pages corresponding to the 7 annexes, 89 figures, 51 tables, and 154 bibliographical references.

The paper, as it is structured on chapters, follows a gradual approach, through which each chapter presents aspects that were subsequently introduced in the design and elaboration phase of the developed analysis and the created application. The paper presents in a synthetic and systematic way the own researches, the result of the coordination of the efforts of conception, documentation and of data collection and processing.

The first part of the doctoral thesis is dedicated to the current state of the conceptual, legislative and methodological framework of major risk management specific to critical infrastructures in the field of explosives for civil use, structured in three chapters, as follows:

Chapter 1, entitled *"Analysis of the regulatory regulatory framework for research"*, is devoted to a brief presentation of the European and national legislative framework on major-accident hazards related to activities involving hazardous substances, including hazardous substances in the form of explosives. for civilian use. The results of the analysis carried out in this chapter are the basis for detailing the study on the assessment and reduction of risks associated with industrial sites for the storage of explosives.

Chapter 2 *"The current state of the conceptual and methodological framework for addressing critical infrastructures in the field of explosives for civil use"*, presents in the first part the concept of critical infrastructure, its definition, identification criteria, typology of risk elements and national and European infrastructure system critical. It also defines the criteria on the basis of which explosive storage sites fall into the category of critical infrastructure. The second part of the chapter presents notions of explosives for civilian use starting from their definition, continuing with the legislative aspects regarding the storage, transport and use of explosives. In the final part are presented technical - theoretical notions on the composition, characteristics and classification of explosives for civilian use.

Chapter 3 *"Current state of knowledge in the field of quantitative analysis of the risk associated with explosive deposits"* - this chapter presents several researches carried out over time in the field of explosive risk associated with explosive deposits, according to different approaches, in which the approach based on the study of explosion-resistant structures, the severity of the effects of the explosion, the approach based on numerical models, the approach based on the dynamics of the explosion propagation in the air and underground, the consequences of the explosion or its effects on the ground and surface. based on the evaluation of the system according to its components, finally presenting some procedures for quantifying the risks used in this research.

The second part of the paper, structured on three chapters, presents its own theoretical and applied contributions with the character of originality of the doctoral research, as presented below:

Chapter 4 entitled *"Eventual analysis of accident scenarios for explosive storage infrastructures and the logical model of accident sequences. The development of explosion scenarios "* is largely an original contribution to the originality of the doctoral research and addresses the analysis of event trees (AAE), with an emphasis on how the results of this analysis can be used to adopt additional measures. security. The first stage of the quantified risk assessment for explosives deposits requires a complete analysis of all the possibilities of the

initiating events that could lead to a potential explosion, materialized either by detonation or by explosion or the combination of these two types of explosive phenomena. Next, the security measures that could be adopted are analyzed, by installing technical security barriers or by applying other measures of an organizational or other nature, so as to aim at preventing any possibility of occurrence of the already identified initiating event. Accidental sequences are delimited, consisting of an initiating event, failures or specific successes of the functionality of the protection measures, including here the human responses (operator intervention). Next, the accidental sequences are grouped into classes (branches of the event tree) in which the sequences in a branch result in the same consequences. Finally, the possible occurrence frequency for each of the accident sequences (scenarios) is calculated and the value of the risk level is determined by corroborating the frequency with the severity of the consequences of the explosion, according to a methodology developed based on the principles of the safety barrier analysis method. LOPA), adapted to be able to ensure a better delimited classification of risk levels.

Chapter 5, entitled *"Experimental research on the risk of explosion generated by explosives for civilian use in industrial sites for the storage of explosives"* is also a large part of the original personal contribution of doctoral research and presents the methodology of analysis, evaluation and classification of major-accident hazards (explosion) in the case of explosives depots, quantification of possible effects on neighborhoods and human health, also in this chapter being presented the methodology for delimiting emergency planning areas. Further, for the comparative analysis of the explosion risk generated by explosives for civil use in industrial sites for the storage of explosives, checklists were developed to identify the technical and / or organizational safety measures applied to each of the analyzed deposits, next step performing an individual analysis of storage sites, based on checklists. At this stage of the work, based on the checklists presented, a number of 7 sites for the storage of explosives in Romania were verified. In the final part of the chapter, based on the data collected during the individual analysis, a comparative analysis of the risk of explosion generated by explosives for civil use in the 7 industrial sites for storage of explosives mentioned above was performed, drawing specific conclusions for each of the possible factors. triggers analyzed, the data being included in comparative centralized tables for each of these triggers. In these comparative tables, the trees of events corresponding to the analyzed factor were presented and, after the risk level assessment, the results of this assessment were centralized in the form of a diagram, which would provide a clearer picture of the risk level variation with the introduction of risk measures. previously identified security requirements.

Chapter 6, *"Substantiation, development and validation of the specialized computer application Resicex of the explosion risk management system specific to critical infrastructures in the field of explosives for civil use"* has a complex structure and also constitutes its own contribution, with originality of doctoral research. This chapter sets out the criteria for developing a specialized IT application, which can be an analysis tool from the design phase of a warehouse, but also a tool that can be used to quickly identify existing risks on a site and of the security measures that can / should be implemented.

This application, hereinafter referred to as RESICEX (Explosive Risk Specific to Critical Infrastructure in the Field of Explosives for Civil Use), was developed, based on the established criteria, the paper presented the design principles, installation steps and operation of the application, after which, in the final part of the paper, used the application to conduct the case study for an explosives storage site.

In the last part of the paper, **Chapter 7** "*Conclusions, contributions and future research directions*" are presented the main aspects of the study and analysis of concepts, methods, phenomena, applications and results obtained. The presentation of the personal contributions in the field of the topic studied in the doctoral thesis is structured on the 2 components, theoretical contributions, respectively applied contributions, a special attention being paid to the way in which they can be implemented and capitalized. The main areas of research in which future efforts should be directed to reduce the risk of explosion from civilian explosives in industrial explosive storage sites have also been identified.

4. The degree of complexity and novelty of the research

The novelty of the paper derives from the procedural approach, gradual, based on the latest theories, knowledge, principles and hypotheses in the field of risk management, in a form that allows understanding the concepts and phenomena and analysis of different types of risks associated with systems technical / labor investigated. The degree of novelty of this doctoral thesis stems from the fact that at the beginning of the study, the author did not have predefined / predetermined opinions about the emerging framework of research development. As a result, the study was planned in a way that allowed the selected and applied methods as well as the data collected to define the nature of the relationships between the elements, parameters and significant factors. Thus, this thesis can be considered more as an exploratory study than a confirmatory study, as it aims to define the possible relationships in the most general form and then allow multivariate techniques to estimate the relationship (s) that are decisive for the development of solutions. The working methodology proposed in chapters 4 and 5 and the computer application RESICEX presented in chapter 6 can be appreciated as a novelty at national level. The issue of the thesis was structured so that the scientific novelty character and the practical and applicative value of the paper result from several elements, highlighted in the final chapter.

The degree of complexity is derived from the very importance of the national and international legislative context, the nature of the systems and risks addressed as well as the dynamics of the evolution of scientific research in the field of OSH and the prevention of risks of major accidents. Given the intrinsic nature of the systems approached, the importance of the legislative, normative and regulatory context, the accelerated information explosion, as well as the evolution of scientific progress in the field, for the conceptualization of the system and the theoretical substantiation of the models used. industrial engineering, occupational safety and health, industrial safety, industrial management, legislation, probability theory, computer science, etc.), which gives the doctoral thesis a certain interdisciplinary and multidisciplinary character necessary to meet the specific objectives of the research.

5. Personal contributions

From a scientific point of view, the original contributions are reflected by the results of research obtained in different stages of the doctoral program and which have been described in the doctoral thesis as follows. This doctoral thesis describes original tools and solutions to support specialists involved in the explosion risk assessment specific to industrial sites for the storage of explosive materials and other factors interested in fulfilling the obligations under national legislation on risk minimization.

I consider that the theoretical foundations and the methodological and applied tools that I developed during my doctoral internship, summarized below, are original contributions in the field of research aimed at increasing the level of security in industrial sites where activities are carried out with explosives. Personal contributions in this field include both theoretical and practical aspects.

A. From the point of view of the bibliographic researches and the analysis of the current state of the approached topic:

A.1. Carrying out in-depth research aimed at evolving the regulatory regulatory framework for the control of major-accident hazards involving dangerous substances;

A.2. Carrying out a documentary study aiming at the current state of the conceptual and methodological framework for approaching the critical infrastructures in the field of explosives for civil use;

A.3. Carrying out a documentary study on explosives for civilian use starting from their definition, continuing with the legislative aspects regarding the storage, transport and use of explosives, technical - theoretical notions regarding the composition, characteristics and classification of explosives for civilian use;

A.4. Carrying out a documentary study on the current state of knowledge in the field of quantitative analysis of the risk associated with explosives deposits, based on the literature and studies conducted over time in this regard;

A.5. The objective of developing a methodology directly applicable to non-experts required and required that the documentary study in the literature focus primarily on the provisions of applicable law and applicable security standards, which was met in a timely manner. quasi-exhaustive;

A.6. The bibliographic references reflect a constant concern for the most relevant research in the field of occupational safety and health, focusing on the specific field of security of industrial explosive storage sites, proving a special interest in keeping the information up to date.

B. From the point of view of setting specific research objectives:

B.1. Identification, based on the analyzes performed, of the difficulties and problems relevant for the specific aspects related to the management of the risks generated by the storage of explosive materials;

B.2. Detecting the specific objectives and clearly establishing the directions of action for achieving the intermediate objectives circumscribed to the theme of the paper based on carefully selected criteria;

B.3. Identifying the possibility of developing a computer application, accessible to users without advanced knowledge in the field of computer science, as a way to facilitate the implementation of applicable preventive measures.

C. From the point of view of theoretical contributions

The significant theoretical contributions included in the doctoral thesis are the following:

C.1. Brief description of the evolution, structure and content of the national and Community legislative framework on the evolution of the regulatory legislative framework on the control of major-accident hazards involving dangerous substances;

C.2. Carrying out a documentary study aiming at the current state of the conceptual and methodological framework for approaching the critical infrastructures in the field of explosives for civil use;

C.3. Elaboration of a bibliographic study on explosives for civil use starting from their definition, continuing with the legislative aspects regarding the storage, transport and use of explosives, technical - theoretical notions regarding the composition, characteristics and classification of explosives for civil use;

C.4. Highlighting the current state of knowledge in the field of quantitative analysis of the risk associated with explosives deposits, based on the literature and studies conducted over time in this regard;

C.5. Synthesis of the results of fundamental and applied research, as well as of the experience of nationally and internationally recognized specialists in the field of industrial safety, regarding the general objectives and main stages of the risk analysis and assessment approach, required input data, types of results obtained and algorithms used to quantify the level of risk;

C.6. Integrative approach to preventive and restrictive safety measures, in relation to the influence that may be exerted by the hazards associated with industrial sites for the storage of explosives;

C.7. The objective need to control the occurrence and materialization of occupational risks to which any economic organization is exposed, has led to the emergence of a new branch of scientific management: risk management, which also integrates the risk to safety and health at work. In this context, the systematic approach of the research topic was made from the perspective of providing a useful tool to support the implementation of specific legislation in the field, given the efficient use of human, material and financial resources, which are always crucial constraints for employers;

C.8. Carrying out the analysis of deposits by the event tree method (SEA), with an emphasis on how the results of this analysis can be used to adopt additional security measures, in this regard analyzing all possibilities a potential explosion;

C.9. Delimitation of accidental sequences, consisting of an initiating event, failures or specific successes of the functionality of protection measures, grouping them into classes (branches of the event tree) in which the sequences in a branch result in the same consequences; elaboration of the methodology for analysis, assessment and classification of major accident hazards (explosion) in the case of explosives depots, quantification of possible effects on neighborhoods and human health and methodology for delimitation of emergency planning areas;

C.10. Elaboration of the working methodology for the comparative analysis of the explosion risk generated by explosives for civil use in industrial sites for storage of explosive materials, identification of the stages of analysis of storage sites, design and development of working tools of the methodology;

C.11. Establishing the development criteria and design principles of a specialized computer application that can be an analysis tool from the design phase of a warehouse, but also a tool that can be used to quickly identify risks on a site and measures which can / should be implemented.

D. In terms of practical and applied contributions:

Practical and applied contributions consist of the following:

D.1. Identify and analyze all possible occurrences of initiating events that could lead to a potential explosion at an explosives storage site;

D.2. Identification, inventory, analysis and prioritization of security measures that could be adopted, by installing technical security barriers or by applying other measures of an organizational or other nature, so as to aim at preventing any possibility of occurrence of the already identified initiating event and / or limiting the effects of a potential explosion;

D.3. Performing the analysis of explosive deposits by the event tree method (AAE); elaboration of event trees for each type of identified initiating event;

D.4. Delimitation of accidental sequences, consisting of an initiating event, failures or specific successes of the functionality of protection measures, grouping them into classes (branches of the event tree) in which the sequences in a branch result in the same consequences;

D.5. Elaboration of the methodology for analysis, assessment and classification of major accident hazards (explosion) in the case of explosives depots, quantification of possible effects on neighborhoods and human health and methodology for delimitation of emergency planning areas;

D.6. Carrying out the individual analysis of 7 industrial sites for the storage of explosives for civil use, by identifying the possible triggering factors, of the applied safety measures, of the stored explosives, based on the checklists;

D.7. Development and completion of a comparative study of the 7 industrial sites for storage of the analyzed explosive materials, assessment of the risk of explosion for each identified trigger factor, preparation of comparative tables and diagrams on quantifying the level of risk of explosion;

D.8. Establishing the criteria for developing a specialized computer application that can be an analysis tool from the design phase of a warehouse, but also a tool that can be used to quickly identify existing risks on a site and safety measures that can / must be implemented;

D.9. Establishing the design principles and elaboration of the specialized computer application RESICEX;

D.10. Validation of the analysis methodology and the functionality of the RESICEX application through a case study through which an explosives depot is analyzed, with the help of RESICEX.

E. From the point of view of the dissemination of results

During the doctoral internship and the previous documentations I published as first author and co - author a number of 17 articles and scientific papers, as follows (details in tag 7):

- 1. article published in indexed journals Web of Science - WoS (ISI);
- 7 scientific papers published in BDI indexed specialized journals;
- 7 papers published in the volumes of International Conferences held in the country;
- 1 paper presented at a symposium organized by the UPET Doctoral School
- The occupational standard for surface fireworks, elaborated by INCD INSEMEX Petroșani, work for which I was part of the validation commission

Keywords: explosive deposit, Seveso,, explosion scenario, trigger, safety barrier

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