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ASSESSING THE RISK OF TERRORIST ATTACKS AGAINST TECHNICAL INFRASTRUCTURES INTENDED FOR THE STORAGE OF EXPLOSIVES FOR CIVIL USES

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Abstract: *The paper presents the results of the theoretical and practical research on the development of the infrastructure for assessing the risk of terrorist attacks associated with undesirable events such as major accidents that can occur at explosives storehouses. The scientific research was carried out within the framework of Project PN 16 43 02 15 - CORE Program titled "Researches regarding the increase of security degree in the technical infrastructures for storing explosives for civil uses". The use of the DIRE version 1.0 software package specialized in the field of risk assessment of terrorist attacks on explosives storehouses has provided the necessary premises for an objective and highly accurate assessment of this type of risk in the technical infrastructure and the quantification of the degree of damage to the human component and on-site or neighbouring targets, as well as to the area in their proximity***.**
Keywords: *terrorist attacks, infrastructure, civil explosives*

1. Introduction

The implementation of the SEVESO Directives is aimed at preventing major accidents involving dangerous substances and limiting their consequences for man and the environment. The analysis of national and international legislative regulations on the prevention and combating of acts of bad faith at industrial sites in the field of explosives for civil uses highlights the following: (1) Acts of bad faith can (and under certain circumstances must) be taken into account in the process of assessing major accident hazards; (2) The contents of the safety report and contingency plans shall be structured so that acts of bad faith are dissociated from other causes which may lead to the occurrence of a major accident.

Thus, in setting up the scenarios on the occurrence of an unwanted event falling under the SEVESO directives, such as a major accident involving dangerous substances, it is imperative to iterate the main stages of the process, namely: risk identification, assessment and hierarchy, based on profound knowledge; account must be taken of their maximum level of manifestation, their simultaneity and their chain development, aspects which establish that planning are to take into account both individual risks and situations of combined or interdependent manifestation, to ensure a rapid preparedness, protection and mitigation response [1].

2. Situation of industrial accidents caused by international acts of bad faith

In France, the central public environmental authority decided in 1992 to create a specialized structure in the Directorate for the Prevention of Pollution and Risks (Direction de la Prevention des Pollutions et des Risques – D.P.P.R.) in order to centralize and capitalize on the experience gained in the field of industrial accidents, namely: Bureau of Analysis of Industrial Risks and Pollution (Bureau d′Analyse des Risques et Pollutions Industrielles – B.A.R.P.I.) [2].

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To accomplish the work assignments for which it was created, B.A.R.P.I. developed a computerized database called A.R.I.A. (Analyse Recherche et Information sur les Accidents), which centralizes all information on accidents, serious pollution and significant incidents in industrial facilities that are likely to affect the environment, security, safety or public health. The typology of events recorded in the A.R.I.A. database, according to the main features of accidents, indicates that fires and emissions/discharges of hazardous substances are the most common forms of accidents. Thus, of a total of 1,073 accidents in 2018, fires represent 60% and emissions/discharges of dangerous substances 44%.

Several causes may be the origin of the same event, and they are known only in a proportion of 30 ÷ 40%. The production of an accident is often preceded by precursor signs and elementary technical or organizational failures, more or less apparent, whose importance is often underestimated. The detection, analysis and treatment of these "weak signals" must be well organized at the level of economic operators to optimize prevention measures and track their effectiveness over time.

Table 1 presents the main causes of accidents recorded in France in 2018 and between 2002-2018.

Table 1

Causes	**Period**	
	2002-2018 [%]	**2018 [%]**
Organizational and human factor, of which:	49	61
Poor organization (rules, procedures, etc.)	29	45
Poor control of some products	16	21
Inappropriate use of hazardous products	1.6	0.9
Insufficient or unsuitable intervention	1.9	0.2
Abandonment of dangerous products/equipment	2.6	0.5
Material defects:	53	51
Proved or suspected acts of bad faith	7.5	6.9
External causes, of which:	9.5	11
Loss of utilities (water, electricity, etc.)	0.8	0.5
Off-site accident	6.9	0.3
Aggressions of natural origin	6.4	5.6
Other external causes	0.9	3.1
Major pollution	2.4	-
Other causes	7.0	2.8

The acts of bad faith alone, either proved or suspected, represented 7.5% of the known causes of accidents produced in France during the period 2002-2018 (with a share of app. 6.9% in 2018). Also, in France, between 47 and 66 industrial accidents generated by acts of bad faith were recorded annually, taking into account the reference period 2013-2018.

The statistics of acts of bad faith produced in France between 2013 and 2018 are presented in Table 2 (data extracted from the A.R.I.A. database).

Table 2

Types of acts of bad faith	**Year**					
	2013	**2014**	**2015**	**2016**	**2017**	**2018**
Fire	33	57	29	39	29	31
Water pollution	8	9	10	9	9	8
Soil pollution	4	-	7	2	1	2
Air pollution	1	-	1	1	1	2
Theft of dangerous products	1	-	1	1	2	5
Suspicious deposits	1	-	-	1	-	1
Sabotage / Risk of contamination of population	1	-	1	4	3	1
Miscellaneous (storage of hazardous waste, etc.)	-	-	-	-	2	-
Total	**49**	**66**	**49**	**57**	**47**	**50**

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The theft of dangerous products (dynamite, ammonium perchlorate, etc.), the placement of suspicious packages at an industrial site and the sabotage of drinking water treatment and distribution facilities constitute a particular form of acts of bad faith, less frequent, but hinting to the possibility of occurrence of terrorist actions [3].

Consequently, it can be argued that acts of bad faith are a cause of accidents at industrial sites that should not be neglected by any means.

3. Analysis of the vulnerability and safety of industrial sites in the field of explosives for civil uses

The study of the safety of industrial sites first requires an analysis of the vulnerability of the facilities (identification of sensitive points and vital points) and the implementation of security measures to prevent the risk of acts of bad faith and to reduce their consequences as much as possible [4].

The predictive analysis of terrorist risk aims at assessing the degree of vulnerability of an industrial site, starting from the classification of terrorist acts both according to their level of preparedness / complexity / determination and the level of protection required to deal with different types of possible attacks. In order to achieve the objectives pursued, terrorist actions may target either the population directly or sensitive points such as industrial sites, so that these actions would cause in most cases many victims, material damage and, if possible, be as spectacular as possible (total destruction of an industrial site, generation of domino effects, etc.).

It can be said that an undesired event such as an accident at an explosives storehouse can occur in the following circumstances: military, air or land attack; terrorist attack; a serious human error; an accident in the vicinity of the storehouse.

The risk level can thus be defined as the product between the probability of occurrence of an event and its effects, according to the equation:

Risk (**R**) = Probability (**F**) x Consequences (**I**) (1)

Quantification of the risk level is performed according to the matrix presented in Table 3, namely the *Risk Matrix for the identification of major accident hazards*.

Table 3

Consequences / Probability	Insignificant I1	Low I2	Medium I3	High I4	Very High I5	Catastrophic I6
F6	6	12	18	24	30	36
F5	5	10	15	20	25	30
F4	4	8	12	16	20	24
F3	3	6	9	12	15	18
F2	2	4	6	8	10	12
F1	1	2	3	4	5	6*

Legend:

>16	Unacceptable risk. Major investments are required to reduce the risk. If these are not feasible, it is necessary to cease activity.
6*÷16	Acceptable risk, with the need to adopt measures to reduce probability and consequences (ALARP - As low as reasonably practicable)
1÷6	Acceptable risk

Interpretation of the level of consequences of a major accident on human health, the environment, as well as the resulting financial losses is presented in Table 4.

The probability classes considered are: **F1 - almost impossible** - it is unlikely that the event occurs both at the level of the analysed facility and at similar existing facilities ($\leq 10^{-5}$/year); **F2 - unlikely** - it is unlikely that the event occurs at the level of the analysed facility, it is likely to occur at similar existing facilities once during their operation ($10^{-4} \div 10^{-3}$/year); **F3 - rarely -** the event is likely to occur at the level of the existing facility once during its lifetime ($\sim 10^{-2}$/year); **F4 - occasionally -** the event is likely to occur several times over the lifetime of the facility ($\sim 10^{-1}$/year); **F5 - often** - the event is likely to occur several times over the facility's lifetime (annually); **F6 - frequently -** the event can occur several times a year.

Accidents with an acceptable risk level (1÷6) require routine actions, and the prevention and mitigation of their effects imply normal procedures specific to the workplace.

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Table 4

	Insignificant I1	**Low I2**	**Medium I3**	**High I4**	**Very High I5**	**Catastrophic I6**
Health/ Security	No effect	Minor injuries	Injuries with hospitalization	Temporary disabilities	Permanent disabilities	Fatalities
Environment	No effect	Light damage, rapid remediation	Important damage, possible remediation	Major damage, difficult remediation	Severe damage, remediation virtually impossible	Serious damage, ecological disaster
Financial losses (thousand €)	< 5	5÷10	10÷50	50÷250	250÷1,000	> 1,000

Accidents with an acceptable level of risk, but with the need to adopt measures to reduce the probability and consequences - *ALARP* (6*÷16) require prompt prevention and intervention actions, involving the top management of the economic operator and external intervention forces. Very unlikely, speculative accidents, but whose consequences are catastrophic (6*) are also included in this category [5,6].

Accidents with an unacceptable level of risk (>16) require immediate action and priority investments in order to prevent and mitigate the consequences. If these investments are not feasible or do not lead to the desired results, it is advisable to cease activity.

The generalized terrorist attack, a more realistic scenario for the current international situation, can only be achieved by infiltration on the part of a group of well-trained combatants. In the latter case, the storehouse security system must be provided by armed security personnel, equipped with appropriate logistics in accordance with applicable regulations, necessary to resist with maximum efficiency. Moreover, any intrusion attempt can be detected in due time, given that the storehouse is secured against intrusion by a double barbed wire perimeter fence, and the entire perimeter security area has permanent video monitoring.

In this scenario, the consequences of a series of events leading to the explosion of all the existing targets at the level of the storehouse were analysed. The consequences of the explosion accidents for each target are those specific to the explosion scenarios for each target of the explosives storehouse considering the maximum quantities of hazardous substances that can be stored.

In conclusion, the risk level of the accident investigated is: probability level: **F1 (almost impossible)**; consequence level: **I6 (catastrophic)**; risk level: 1 x 6 = **6*, acceptable, with the need to adopt measures to reduce probability and consequences.**

The targets affected by such an accident are listed in the table below.

Table 5

Scenario	**Substance involved**	**Radius of planned areas**				**Internal Emergency / External emergency**	**Targets and areas involved**		
		The zone of risk area with domino effect	**The zone of risk area with high mortality (m)**	**The zone of risk area with irreversible damage (m)**	**The zone of area of attention (m)**		**High mortality risk area**	**Risk area with irreversible damage**	**Area of attention**
Disaster scenario - terrorist attack	Explosive materials stored	-	(to be determined using DIRE Version 1.0)	(to be determined using DIRE Version 1.0)	(to be determined using DIRE Version 1.0)	(check whether the scenario is inside or outside the site)	Inside the storehouse: -targets the entire explosives storehouse; Outside the storehouse: - civil and/or industrial targets/ dwellings located at a predetermined distance (m)/	Outside the storehouse: - security and protection unit/ dwelling area located at a preset distance (m)/forests and/or pastures in the immediate vicinity of the explosives storehouse.	Outside the storehouse: -dwelling area up to a preset distance (km)/forests and/or pastures in the vicinity of the explosives storehouse.

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							forests and/or pastures (no. of hectares), near the explosives storehouse.		
	Population involved	-	-	-	-	-	Approximate number of people exposed.	Approximate number of people exposed.	Approximate number of people exposed.

4. Computerized risk assessment of terrorist attack at INSEMEX Explosives Polygon

DIRE Version 1.0 is a specialized automated analysis software for assessing susceptible risks and vulnerabilities, as a result of potential terrorist actions or other incidents with explosions (Figure 1) [7,8].

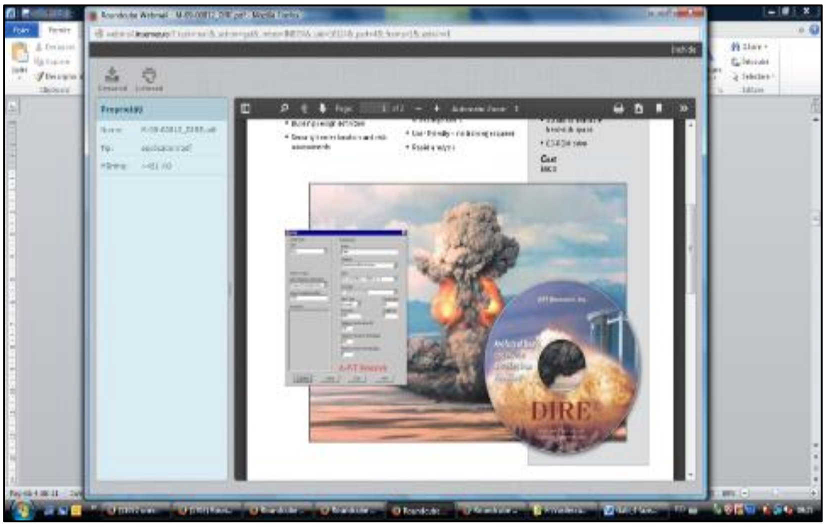

Fig.1. Specialized software package DIRE Version 1.0

The *User Input window* is displayed after the start-up screen disappears, and contains multiple input fields and a command line row at the bottom of the window (Figures 2 and 3). The *Output window* is displayed after the user has entered all the required information in the *User Input* window and has pressed the [Calculate] button, (Figure 4).

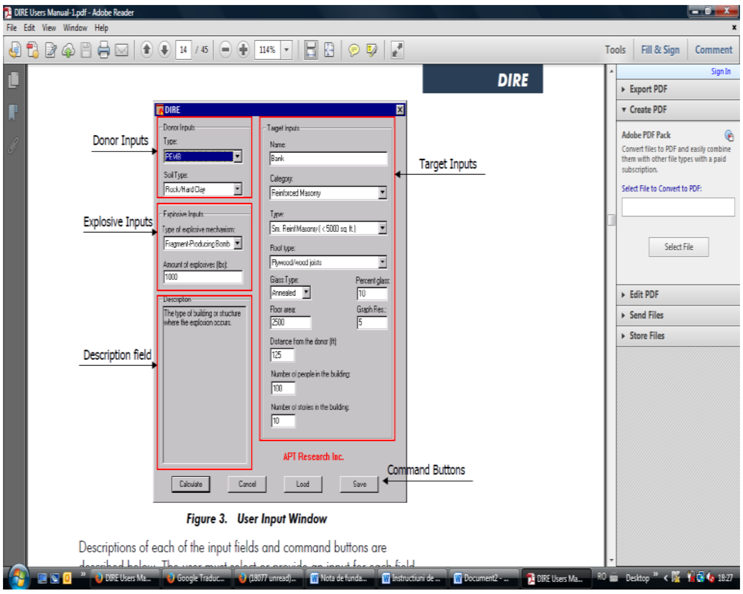

Fig.2. User Input Window

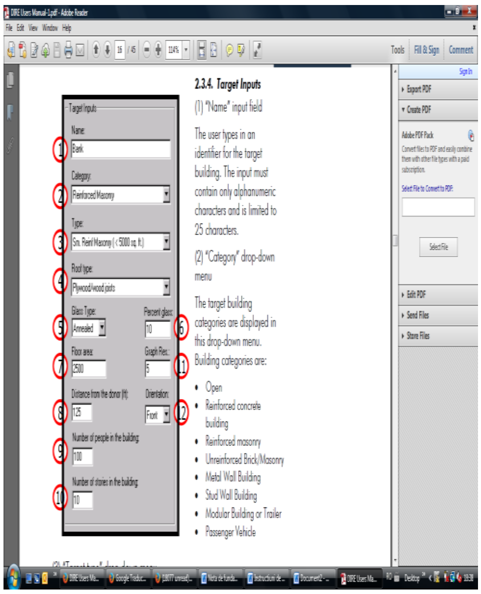

Fig.3. Target Inputs

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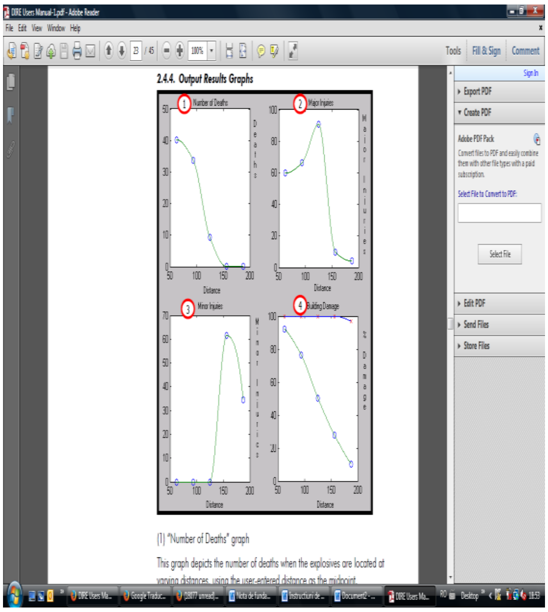

Fig.4. Output Charts

To highlight the use of the specialized software DIRE version 1.0, please find below some examples of results obtained from the simulation of specific scenarios that have been configured on the INSEMEX site, where there is an underground explosives storehouse (Figure 5).

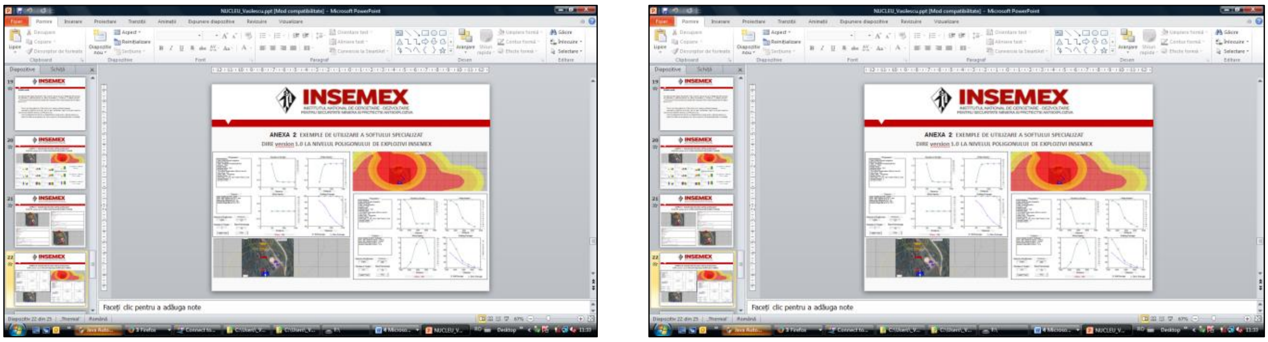

Fig.5. Risk curves and contour map for INSEMEX explosives storehouse

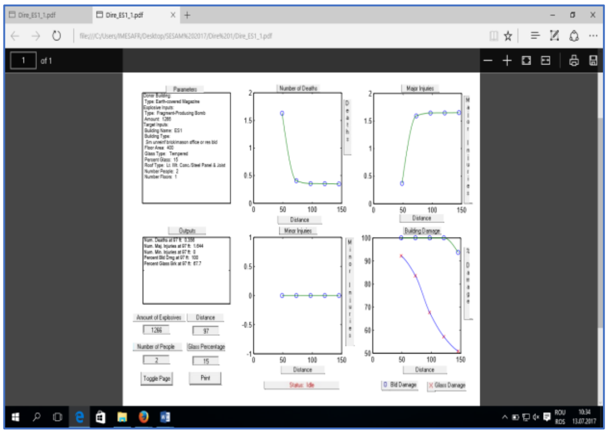
Fig.6. Result curves – Explosives storehouse (Mass Explosion)

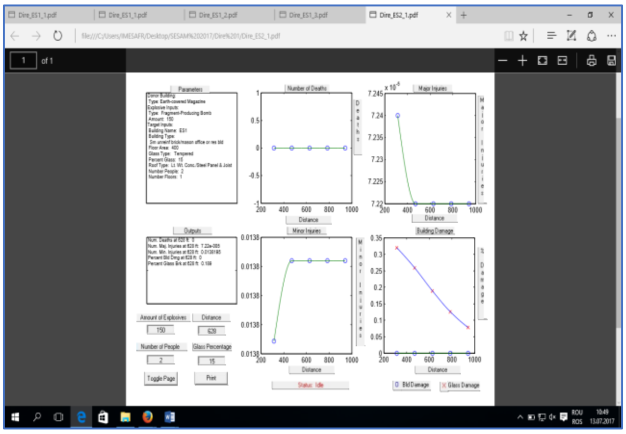
Fig.7. Result curves – Explosives storehouse (Bomb Explosion)

Result curves obtained from a computer simulation of the accident scenario following a terrorist attack (mass explosion and bomb explosion with fragment projection), which was configured on the INSEMEX site (Figures 6 and 7), highlights the statistical situation of the number of deaths, major and minor injuries, and the degree of destruction of buildings and the breakage of windows at the explosives storehouse located on the polygon site.

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5. Conclusions

From a global point of view, an undesirable event such as an accident at an explosives storehouse can occur in the following circumstances: military, air or land attack; terrorist attack; a serious human error; an accident in the vicinity of the storehouse.

The consequences of an event such as an explosion-related accident are due to the following factors: overpressure of the shock wave front (the mechanical effect of the explosion), which causes destruction of structures and human casualties; thermal effect of the explosion, corresponding to the model of the sphere of fire, which initiates fires at the level of neighbouring targets and causes the death of exposed persons; generation of gaseous pollutants (nitrogen oxides) as reaction products.

The use of the full DIRE v1.0 software package specialized in the field of risk assessment of terrorist attacks on storehouses of explosives for civil use that was purchased under the PN 16 43 02 15/2016-2017 Project – CORE Program, provides the premises necessary to estimate and appraise, under objective and highly accurate conditions, this type of risk and quantify the degree of damage to the work systems and adjacent areas located in their proximity.

To highlight the use of the DIRE version 1.0 software, the paper presents some examples of results obtained from simulating a specific accident scenario with two variants (mass explosion and bomb explosion with fragment projection), which was configured at the INSEMEX site, where there is an underground explosives storehouse.

Acknowledgement

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