Evaluation of the Most Important Fire Threats of the Building

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***Abstract* - The article deals with analysing the most important threats in industrial buildings and also evaluates the top 12 most important threats using a quantitative and qualitative threat analysis method, dividing them into primary, secondary and tertiary according to their significance. Based on the results, preventive measures can be created and applied for the most important threats that could significantly affect the proper operation of the building.**

Keywords— analysis, fire threat, fire protection, fire safety, safety

I. INTRODUCTION

Human society has sought to protect itself from threats since its early beginnings. Threat protection is a safety feature. Safety is a situation where threats are minimised to the lowest possible level. Unlike safety, security is an activity of protecting our houses, flats and companies. Safety and security have many categories. Individual categories are constantly evolving based on the development of society. The concept of security began to be addressed in several ways due to the events in 1989 (change of political regime) and 11 September 2001 (attack on the World Trade Centre in New York). One of the historically first studied types of safety is fire safety, which is one of the basic types and categories. It deals with the protection of human lives, property and animals, and also with minimising possible threats associated with fire. Fire protection is managed by an integrated security system, specifically firefighters. [1] [2]

Due to global warming, more fires are currently occurring. Fires occur in houses, forests, meadows and other environments where the temperature rises. The solution to this problem is a preventive measure. If fires arise, a fast and effective fire reaction is essential. An adequate recommended response should be an increase in the number of members of fire protection, the education of the population and the overall minimisation of threats. The article defines the most significant fire threats and risks for an industrial building and describes two risk analyses. The resulting threats and risks are evaluated and divided into three groups (primary, secondary and tertiary) according to their significance.

II. METHODS

This chapter is divided into two parts: analyses and procedure.

A. Analyses

Within some of the methods, two analyses will be used to evaluate the most critical threats and risks in fire protection of the building. Specifically, it is a semi-quantitative risk analysis (SQRA) and qualitative analysis of the correlation of risks (QRA).

B. Procedure

Firstly, it is essential to identify the most significant threats. In the case of calculating the risk analysis, the top 20 most significant threats related to fire protection are used and applied in SQRA, from which the twelve most significant risks are evaluated. Then, QRA divides these twelve risks according to their significance into primary, secondary and tertiary. The general risk assessment procedure is:

- selection of the top 20 most important threats in the field of fire protection,
- application of SQRA,
- evaluation of the twelve most important threats,
- application of QRA,
- labelling each of the twelve most significant threats according to their significance as primary, secondary and tertiary.

1) Selection of the 20 most important threats in the field of fire protection

This is a selection of 20 critical threats in fire protection for a specific type of building.

2) Application of SQRA

According to this method, the most significant threats are determined through 3 factors: risk, asset and vulnerability. It is based on the formula:

$$R = A * T * V \quad (1)$$

Where:
R – risk,
A – asset,
T- probability of the threat occurring,
V – vulnerability.

It is necessary to determine the point value to evaluate the determining factors.

An asset is a component of a threat that has a specific value for a given system. The asset can be for example life, health, tangible or intangible property, finances and other things that have protected importance for human society. The threat is a potential cause of a negative situation that may impact the system about the identified assets and also it can cause harm or negatively impact the reference object in case of exposure. The threat can be of natural origin (caused by nature) or anthropogenic origin (caused by a human). Vulnerability generally expresses a weak point of the reference object and its assets through which a security breach can occur. Also, it can be defined as a quantity expressing the degree of ease of causing harm to the reference object and its assets (negative impact), and at the same time, it can be understood as the opposite of resilience. Vulnerability also expresses the susceptibility of the protected interest to damage. Vulnerability has a set of values for the risk analysis process. Points will be assigned in the range of 1 to 5, where 5 points mean the highest asset, probability of threat and a high vulnerability value.

3) Evaulation of the twelve most threats

The twelve most significant threats are selected from the resulting point values, i.e., the twelve threats with the highest sum of points.

4) Application of QRA

The qualitative method is based on the interrelationship between identifiable threats based on the threat's degree of activity and passivity compared to other threats. The process of implementing the qualitative method is multi-level.

Firstly, an inventory of threats is established, followed by an analysis to express the interrelationships between the identified threats through a table of threats.

Secondly, two coefficients are expressed: the activity coefficient, which expresses the total threat potential to cause additional threats, or the expression of passivity, which expresses the number of threats that the given threat may cause. [3]

To compute the coefficients, the formulas below are used:

$$C_A R_i = \frac{\sum R_i}{x-1} \quad (2)$$

$$C_P R_i = \frac{\sum R_i}{x-1} \quad (3)$$

Where:

$C_A R_i$ – activity coefficient,

$C_P R_i$ – passivity coefficient,

$\sum R_i$ – the sum of threats (the horizontal axis shows the activity coefficient and the vertical one the passivity coefficient)

x – total number of threats. [3]

Following the calculations, we get the values of the coefficients, which we multiply by the number 100 to convert them to a percentage value. [3]

Subsequently, these values are plotted in a graph that prioritizes threats in terms of their potential.

We need two lines that divide the graph into four parts. It is necessary to divide the graph into four segments to determine the most significant threats. The first section is projected to account for 80% of the most serious threats. [3]

To compute the axes, the following mathematical formulas are applied:

$$A_A = C_{Amax} - \frac{(C_{Amax} - C_{Amin})}{100} * 80 \quad (4)$$

$$A_P = C_{Pmax} - \frac{(C_{Pmax} - C_{Pmin})}{100} * 80 \quad (5)$$

Where:

A_A – vertical axis for activity coefficient,

A_P – horizontal axis for passivity coefficient,

C_{Amax} – maximum value for the activity coefficients,

C_{Amin} - minimum value for the activity coefficients,

C_{Pmax} – maximum value for the passivity coefficients,

C_{Pmin} – minimum value for the passivity coefficients.

Values not equal to 0 are calculated for greater precision. [3]

5) Assigning each of the twelve most significant threats according to their significance as primary, secondary and tertiary

These divisions determine which hazards are most important. The segments are divides:

- segment I - primary significant threats - the highest coefficient of activity and, at the same time, passivity,
- segment II and III - secondary significant threats- high activity or passivity coefficients,
- segment IV - tertiary significant threats - low level of both coefficients.

SQRA and QRA and their results point to determining the importance and significance of threat factors for a given building. Whether the analysis and assessment of the importance of threats is applied to a given area of assets or a multi-stage method of QRA of the building, both methods can be considered reliable. In the next chapter, Results, specific threats are applied to the given process, from which the most significant threats are evaluated through 2 analyses.

III. RESULTS

Based on the methods, specific data are applied to evaluate the results. As described in the Methods (Procedure) chapter, the individual results are divided into five parts plus a section with an overall evaluation of the results.

A. *Selection of the 20 most important threats in the field of fire protection*

This is a selection of the 20 most important threats for a specific type of building. It is an industrial building where people, machines and equipment are located (not a specific building, but only a type of building).

The 20 most important fire threats to this type of building are:

- minor fire,
- large-scale fire,
- minor explosion,
- more massive explosion,
- leakage of a dangerous substance,
- flooding,
- increased air temperature,
- overheating of machines and equipment,
- blackout,

- blocked escape exit,
- fewer fire extinguishers,
- non-functional fire protection system,
- disorientation in the workplace,
- untrained staff,
- undefined assembly point,
- unauthorized manipulation of fire,
- smoking in the workplace,
- incorrectly prepared map of escape routes,
- damage to machines,
- work accident. [4]

B. SQRA

Table 1 shows the application of SQRA for the 20 most important threats. The application procedure is in Chapter - Application of SQRA.

Table 1 – Application of SQRA for 20 fire threats

Number	**Threat**	**Asset**	**Probability**	**Vulnerability**	**Risk**
1	Minor fire	4	4	4	**64**
2	Large-scale fire	5	3	5	**75**
3	Minor explosion	4	4	4	**64**
4	More massive explosion	5	3	5	**75**
5	Leakage of a dangerous substances	4	4	4	**64**
6	Flooding	4	2	4	**32**
7	Increased air temperature	2	5	1	**10**
8	Overheating of machines and equipment	3	4	2	**24**
9	Blackout	2	4	2	**16**
10	Blocked escape exit	1	2	3	**6**
11	Fewer fire extinguishers	2	2	4	**16**
12	Non-functional fire protection system	4	2	4	**32**
13	Disorientation in the workplace	1	1	4	**4**
14	Untrained staff	3	2	3	**18**
15	Undefined assembly point	1	2	4	**8**
16	Unauthorized manipulation of fire	3	4	4	**48**
17	Smoking in the workplace	2	4	4	**32**
18	Incorrectly prepared map of escape routes	2	1	3	**6**
19	Damage to machines	4	4	3	**48**
20	Work accident	5	5	5	**125**

These 20 selected threats are primarily related to fire protection. Therefore, threats such as theft or sabotage are not listed. The evaluation of the overall risk from Table 1 through the given three factors and their point scaling of values from 1 to 5 is based on the author's subjective expert assessment.

C. Evaluation of the twelve most important threats

Based on the application of SQRA, the 12 most significant threats are:

- work accident,
- large-scale fire,
- more massive explosion,
- minor fire,
- minor explosion,
- leakage of a dangerous substance,
- damage to machines,
- unauthorized manipulation of fire,
- non-functional fire protection system,
- smoking in the workplace,
- flooding,
- overheating of machines and equipment.

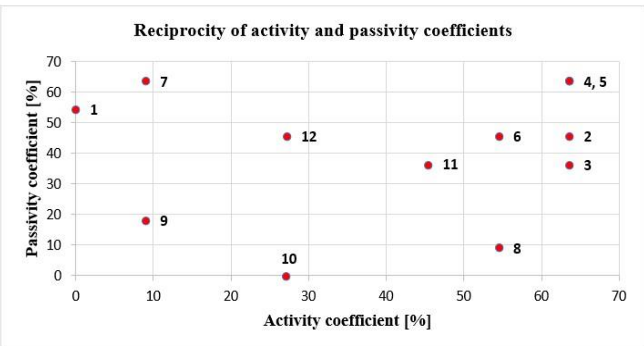
D. QRA

Table 2 shows the application of QRA for the 12 most important threats. The application procedure is in Chapter - Application of QRA.

Table 2 – Application of QRA for the twelve most important threats

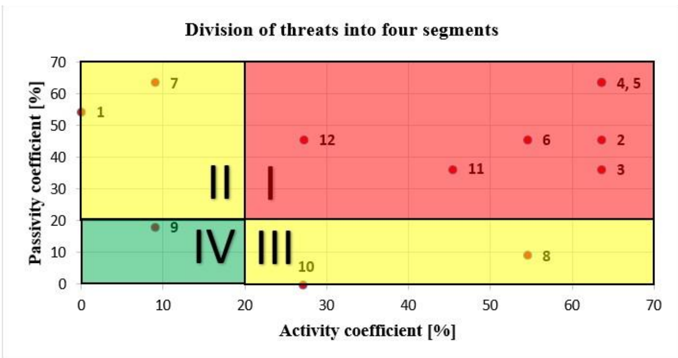
Number	Threat	1	2	3	4	5	6	7	8	9	10	11	12	∑ C_AR_i	C_AR_i [%]
1	Work accident	x	0	0	0	0	0	0	0	0	0	0	0	**0**	**0**
2	Large-scale fire	1	x	1	0	1	1	1	0	0	0	1	1	**7**	**64**
3	More massive explosion	1	1	x	1	0	1	1	0	1	0	1	0	**7**	**64**
4	Minor fire	1	1	0	x	1	1	1	0	0	0	1	1	**7**	**64**
5	Minor explosion	1	1	1	1	x	1	1	0	0	0	1	0	**7**	**64**
6	Leakage of a dangerous substance	1	1	1	1	1	x	1	0	0	0	0	0	**6**	**55**
7	Damage to machines	0	0	0	0	0	0	x	0	0	0	0	1	**1**	**9**
8	Unauthorized manipulation of fire	1	1	1	1	1	1	0	x	0	0	0	0	**6**	**55**
9	Non-functional fire protection system	0	0	0	0	0	0	0	0	x	0	0	1	**1**	**9**
10	Smoking in the workplace	0	0	0	1	1	0	0	1	0	x	0	0	**3**	**27**
11	Flooding	0	0	0	1	1	0	1	0	1	0	x	1	**5**	**46**
12	Overheating of machines and equipment	0	0	0	1	1	0	1	0	0	0	0	x	**3**	**27**
∑ C_PR_i	-	**6**	**5**	**4**	**7**	**7**	**5**	**7**	**1**	**2**	**0**	**4**	**5**		
C_PR_i [%]	-	**55**	**45**	**36**	**64**	**64**	**45**	**64**	**9**	**18**	**0**	**36**	**45**		

Graph 1 shows the reciprocity of activity and passivity coefficients.



Graph 1 – Reciprocity of activity and passivity coeffcients

Graph 2 shows the division of threats into four segments



Graph 2 – Division of threats into four segments

Both graphs are the results of applying the analysis from chapter - Application of QRA.

E. Evaulation of the twelve most significant threats according to their significance as primary, secondary and tertiary

Based on applying a QRA and Graph 2, the 12 most significant threats were divided into three groups according to their significance: primary (Segment I), secondary (Segment II and III) and tertiary (Segment IV).
Primary significant threats are:

- minor fire,
- large-scale fire,
- minor explosion,
- more massive explosion,
- leakage of a dangerous substance,
- flooding,
- overheating of machines and equipment.

Secondary significant threats are:

- damage to machines,
- unauthorized manipulation of fire,
- work accident,
- smoking in the workplace.

A tertiary significant threat is a fire system malfunction.

F. Overall evaluation of the results

An industrial enterprise with people, machinery, and equipment should focus primarily on fire protection due to the high probability of the threat. They should address issues related to possible fires, explosions, leakage of hazardous substances, flooding, and overheating the machinery and equipment. Threats belonging to the group of significant secondary threats do not arise as often as primary ones, but the company should also pay some attention to them. The threat included in the group of significant tertiary threats endangers the company minimally within the fire protection framework. [5]

The resulting assessment of primary, secondary and tertiary threats is mainly intended for the enterprise. In the first step, the enterprise should create preventive measures for primary threats. If these measures are fulfilled sufficiently, it is advisable to create and apply preventive measures for secondary threats. If these measures are also fulfilled sufficiently, it is advisable to create and apply preventive measures for tertiary threats.

It is clear from the results that in the category of tertiary threats (green zone), there is a threat of malfunctioning the fire system. This does not mean that this threat is less significant than the others, but based on the correlation between individual threats and their coefficients of activity and passivity, it does not have as much danger as a fire threat than the other threats.

CONCLUSION

According to Maslow's human survival pyramid, human society must meet its needs. In the first stage, there are physiological needs, including hunger, thirst, breathing and sleep. If these needs are met, there is a second-level need: a sense of safety. Therefore, it is essential to address this need in any situation. In the present study, we have specifically addressed the fire safety, which is one of the oldest types of safety that dates back to antiquity. With the development of human society, it has constantly evolved to its current form.

This article deals with assessing the essential fire threats for an industrial building and it also defines the methods used to assess threats. Two risk analyses were used for evaluation: quantitative (SQRA) and qualitative (QRA). SQRA evaluated 12 significant threats from 20 selected ones. QRA divided these 12 significant threats into three groups according to their significance: primary, secondary and tertiary. Primary threats include minor fire, large-scale fire, minor explosion, more massive explosion, leakage of a dangerous substance, flooding and overheating of machines and equipment. Secondary threats include damage to machines, unauthorised manipulation of fire, work accidents and smoking in the workplace. The tertiary threat is a malfunctioning fire system. Based on the assessment of the essential threats, the industrial enterprise should mainly develop preventive measures for the primary threats, as these can significantly disrupt the operation of the enterprise.

As a part of evaluating the essential threats, the article does not define threats for a specific object because most industrial companies give limited access to the information about threats found in the company to the public.

It is appropriate to analyse the essential threats for other facilities such as schools, offices, hospitals, shopping malls, post offices, and facilities hosting cultural and social events for future research. Based on the analysis, preventive measures could be developed to prevent fires, explosions, leaks of hazardous substances and many other fire threats that could endanger human life or property.

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REFERENCES

[1] Czechoslovakia’s Velvet Revolution Started 30 Years Ago—But It Was Decades in the Making: Time [online]. 2019. Available at: https://time.com/5730106/velvet-revolution-history/

[2] September 11 attacks: Britannica [online]. Available at: https://www.britannica.com/event/September-11-attacks

[3] DELOITTE. (2012). Methodology for ensuring the protection of critical infrastructure in the field of production, transmission and distribution of electricity [online]. 1. Prague, 2012, 55 p. Available at: http://www.hzscr.cz/soubor/metodika-zajis-te-ni-ochrany-kriticke-infrastruktury-v-oblasti-vy-roby-pr-enosu-a-distribuce-elektricke-energie-pdf.aspx (in Czech)

[4] J. Xin, C. Huang. Fire risk analysis of residential buildings based on scenario clusters and its application in fire risk management. Fire Safety Journal 62, 72–78. 2013. Available at: https://doi.org/10.1016/j.firesaf.2013.09.022.

[5] V. Koutsomarkos V, D. Rush, G. Jomaas, A. Law. Tactics, objectives, and choices: Building a fire risk index. Fire Safety Journal 119. 2021. Available at: https://doi.org/10.1016/j.firesaf.2020.103241

[6] E. Ronchi. Developing and validating evacuation models for fire safety engineering. *Fire Safety Journal*. 2021. 120. Available at: https://doi.org/10.1016/j.firesaf.2020.103020

[7] J. Radosavljevic, A. Djordjevic, A. Vukadinovic, D. Ristic. Vulnerability assessment of settlements during

emergencies. *Transaction of the VSB - Technical university of Ostrava* [online]. 2018. Available at: doi:10.2478/tvsbses-2018-0001

[8] V. Osadska. Stochastic methods in risk analysis. *Transaction of the VSB - Technical university of Ostrava* [online]. 2017. Available at: doi:10.1515/tvsbses-2017-0008

[9] L. M. Hulse, S. Deere, E. R. Galea. Fire safety in construction: Site evacuation and self-reported worker behaviour. *Safety Science*. 2022. 145. Available at: https://doi.org/10.1016/j.ssci.2021.105482

[10] S. Slivkova, D. Rehak, V. Nesporova. Correlation of Core Areas Determining the Resilience of Critical Infrastructure. 12th *International Scientific Conference of Young Scientists on Sustainable, Modern and Safe Transport*. 2017. 192, pp. 812-817 [online]. 2017. Available at: doi:10.1016/j.proeng.2017.06.140

[11] D. Rehak, P. Danihelka, A. Bernatik. Criteria risk analysis of facilities for electricity generation and transmission. *22nd Annual Conference on European Safety and Reliability (ESREL). Safety, Reliability and Risk Analysis: Beyond the Horizon*. 2014. pp. 2073-2080 [online]. Available at: doi:10.1201/b15938-312

[12] D. Rehak, P. Novotny. Bases for Modelling the Impacts of the Critical Infrastructure Failure. *7th International Conference on Safety and Environment in Process Industry (CISAP)*. 2016. 55, pp. 91-96. Available at: doi:10.3303/CET1653016