FIRE RISK ASSESSMENT OF FACULTY IN REPUBLIC OF NORTH MACEDONIA

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Abstract: *Fire, as a term, is defined as uncontrolled combustion, either of a part of a structure or of a flammable material in its vicinity, which can cause injury to people and material damage. In order to prevent the occurrence of fire and if it happens to guarantee the safety of tenants, employees, customers, as well as the building itself and the material goods in it, appropriate measures should be taken. The measures depend on the level of risk of fire. For reliable fire risk assessment, it is necessary to conduct an appropriate analysis. The defined risk level directly influences the risk management measures that should be taken to prevent fire or reduce consequences. According the definition given in the ISO 31000:2009 standard, risk management includes risk assessment and management. Fire risk management is a process of developing risk control measures, improving possible existing measures and proper implementation of the envisaged measures, all in order to reduce or eliminate the risk itself. Therefore, fire risk analysis is only one part of the fire risk management process and serves as a basis for deciding whether to take risk mitigation measures or to select appropriate measures to deal with it. Within this research, a fire risk assessment was conducted for Faculty of Business Administration in Kumanovo, North Macedonia. The Euro-alarm, as quantitative method for fire risk assessment was applied. Pathfinder, as a simulator programme, was applied to calculate the evacuation time from the building. Based on the results obtained from the analysis, the risk is quantified with numerical data. Appropriate fire protection measures are determined depending on numerically obtained data.*

Key words: *Euro-alarm Method, Pathfinder, fire, fire risk assessment, fire risk management, hazard, risk*

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1. Introduction

The subject of the research presented in this paper is an assessment of risk pertaining to fire outbreak for the Faculty of Business Administration in Kumanovo, North Macedonia. Measures for protection against fire have been the subject of research, namely, whether they exist and, if they exist, whether they are appropriate and sufficient for the management of hazards causing fires, or whether they should be improved.

The main objective of the investigations presented in the paper has been the definition of the reasons for the occurrence of fire in the school and the damage it will cause. Using these data, an assessment has been made as to whether the structure satisfies some or all necessary conditions for protection against fire and whether corresponding measures are taken to avoid fire outbreak.

Assessment of the risk pertaining to a fire outbreak in the structure has been made by means of a prepared and realized poll based on the Elementary Method for assessment of the risk pertaining to a fire outbreak. In combination with the Matrix Method for risk assessment, classification of structures according to their associated risk related to fire outbreak is made [1, 2].

The final task of this method is to define the range of risk values corresponding to three risk categories.

For more detailed analysis, the quantitative method Euroalarm has been used as the basis for decision making about establishment of an automatic stationary system for fire extinguishing as well as making decisions about additional measures for protection against fire. The justification for the installation of a fire extinguishing system has been defined based on a more detailed analysis and application of the Euroalarm Method, which is the basis for making decision about installation of an automatic stationary system for fire extinguishing as well as taking of additional measures for protection against fire.

2. Fire risk assessment of General Hospital – Main Building

2.1. Basic data on the Faculty of Business Administration

Based on the „in situ“ survey, it was found out that the analysed building of the Faculty of Business Administration is a reinforced concrete structure. The building consists of three floors and basement. The ground floor is used for students, and the first and second floor are used for the academic staff. The heating system is located in the basement, taken care of by the housemaster. The rooms are separated from each other by brick walls (d=20cm), the floor structure is made of reinforced concrete and the roof is wooden structure. In the interior of the building, there are various materials, such as: wooden materials, paper, plastic, etc., which influence the spread of the fire and/or cause the fire to occur. They also contribute to the appearance of smoke and/or the release of toxic products, which would be harmful to the health of those present in the building, as a result of inadequate ventilation. The maximum number of occupants is 130.

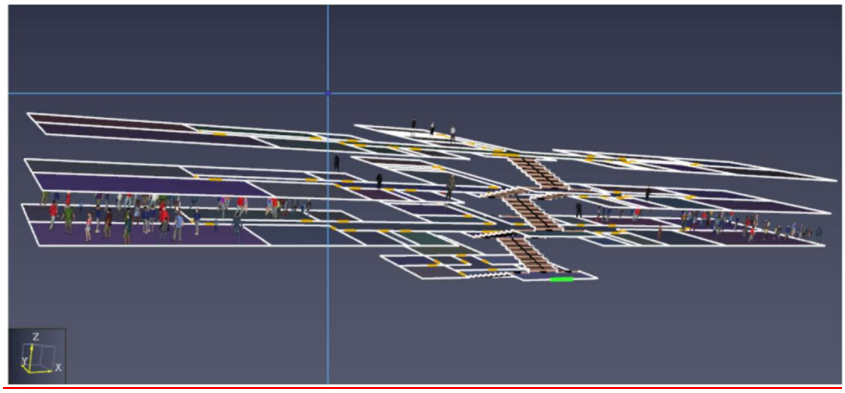


Figure 1. Floor plan of Faculty of Business Administration

The fire risk analysis was conducted by using both, „5x5 Matrix method“ and „Euro-alarm“ method.

2.2. Quality assessment of Risk Pertaining to Fire Outbreak

From the poll conducted at Faculty of Business Administration in city Kumanovo, North Macedonia, it has been concluded that the structure is in very good conditions from the aspect of conditions related to protection against fire.

The probability for fire outbreak in this building is **Unlikely (2)**. This is due to the good-quality interior structure, presence devices for protection against fire, presence of an alarm system for detection of fire, efficient signalling and a sufficient number of exit routes.

The fire risk (impact) is **Very Low (1)**.

According to Matrix Method, the risk value is obtained as product between the probability and the impact:

Value of the fire risk = **fire hazard** (probability**)** x **fire risk** (impact**)**

The numerical value of the fire risk is defined according to Table 1, while the Matrix method is presented in Figure 2.

Based on the obtained results, **the value of the risk is 2** and the **fire risk belongs to category Low**, presented in Table 2.

Table 1. Relationship between fire hazard (probability) and fire risk (impact)

Fire Risk	Very Low	Low	Medium	High	Very High
Fire Hazard	Rare	Unlikely	Possible	Probable	Highly Probable
Value	1	2	3	4	5

	Fire Risk						Risk Category
Fire Hazard		5	4	3	2	1	Low
	5	25	20	15	10	5	Medium
	4	20	16	12	8	4	High
	3	15	12	9	6	3	
	2	10	8	6	4	2	
	1	5	4	3	2	1	

Figure 2. 5x5 Matrix method for defining the numerical value of the fire risk

Table 2. Category of risk to which Faculty of Business Administration is exposed

Structure	Fire Hazard	Fire Risk	Risk value	Risk Category
	Description	Description	Fire Hazard x Fire Risk	
Faculty of Business Administration	Unlikely (2)	Very Low (1)	**2**	**Low**

2.3. Quantitative Assessment of Risk Pertaining to Fire Outbreak

The quantitative „Euro-alarm" method is based on the fire risk of the building (Eq 1) and the fire risk of the building content (people, furniture, etc.) (Eq 2), as two highly related components [4]. The risk related to fire outbreak for the structure depends on the possible intensity and duration of fire due to structural characteristics, i.e., bearing elements of the structure (resistance of the structure to high temperatures) and is computed

$$Ro = \frac{((Po*C)+Pk)*B*L*S}{W*Ri} \quad (1)$$

where:

Ro – fire risk of the building;
Po – coefficient of fire load of the building content;
C – coefficient of combustibility of the contents in the building;
Pk – coefficient of fire load of materials installed in the construction of the building;
B – coefficient of size and position of the fire sector;
L – coefficient of delay in the start of extinguishing;
S – coefficient of a width of the fire sector;
W – coefficient of fire resistance of the load-bearing structure of the building;
Ri – fire risk reduction coefficient.

The fire load has been adopted in accordance with the standard MKS. U.J.1.030 [3] and for classrooms it's value is q=251 (MJ/m^2).The coefficient of fire load of the building content (P_o) is determined according to Table 3.

The coefficient of combustion of the contents in the building (C) depends on the class of fire danger and is given in Table 4. The coefficient of fire load of materials built in the structure of the building (P_k) is obtained based on the calorific value of all combustible materials in the building (Table 5). For RC structure has no caloric value, and $\boldsymbol{P_k}$**=0**. The coefficient of size and position of the fire compartment (B) depends on the size of the fire compartment's floor area, the height of the premises and the number of floors. For four to eight storey building with fire sector from 1500 to 3000 m^2 , height of premises from 10 m to 25 m and one basement storey, this coefficient is **B=1.3**. The coefficient of delay in the start of the intervention (L) depends on the type and equipment of the fire brigade, its distance from the building and the condition of the roads. For territorial firefighting unit where the distance between the fire station and Faculty of Business Administration is 950 m, this coefficient is **L=1.** The fire compartment width coefficient (S) is determined based on the fire compartment width (Table 6). The coefficient of fire resistance of the load-bearing structure of the building (W) is determined depending on the elements from which the building is constructed. In this case the RC structure has fire resistance that is usually higher than 90 minutes (Table 7).

Fire risk can be reduced by using the fire risk reduction coefficient (Ri), in regard to the type of combustible materials, combustion rate, storage method and other factors. In this case the flammability is not particularly high, normal speed of fire spreading is expected and in the process of functioning, there are normal sources of ignition. The value is ***Ri*=1.3**.

Table 3. Coefficient of fire load of the building content (P_o)

Fire load q (MJ/m^2)	0-251	252-502	503-1004	1005-2009	2010-4019
Po	1	2	3	4	5

Table4. Coefficient of combustibility of the content in the building (C)

Category of fire resistance	VI	V	IV	III	II	I
Combustibility coefficient C	1	1	1	1.2	1.4	1.6

Table 5. Coefficient of fire load due to materials built-in the structure of the building (P_k)

MJ/m^2	0-419	435-837	845-1675	1691-4187	4203-8373
P_k	0	0.2	0.4	0.6	0.8

Table 6. Coefficient of the width of the fire compartment (S)

The least width of the fire compartment (m)	up to 20	20-40	40-60	Over 60
S	1	1.1	1.2	1.3

Table 7. Coefficient of fire resistance of bearing structure (W)

Fire resistance in (min)	up to 30	30	60	90	120	180	240
W	1	1.3	1.5	1.6	1.8	1.9	2

By incorporating the defined parameters into Eq. 1, the value of fire risk becomes: ***R_o*=0.54.** In case $R_o < 1$, **the structure should be manual extinguishers as are portable and vehicle mounted extinguishers. This criterion is satisfied.**

The risk related to fire outbreak to which the contents of the structure (danger for the people, the equipment and alike) are exposed is indicated by R_s and is defined by Eq.2.

$$R_s = H \cdot D \cdot F \quad (2)$$

where:
H is coefficient of danger to humans;
D is asset risk ratio;
F is coefficient of smoke action.

The risk factor for people (H) depends on the possibility of timely evacuation of people from the facility and is given in Table 8. The asset risk ratio (D) depends on whether the destroyed property can be recovered and the extent of material losses and is given in Table 9 The appearance of a larger amount of smoke increases the threat to people and property, which is taken into account through the coefficient of action of smoke (F) and is given in Table 10 [4]. For the analysed building, the final value of Rs is: R_s**=2.**

Table 8. Danger to which people are exposed H

Level of endangerment	Coefficient H
There is no danger for the people in the structure	1
There is danger for the people in the structure, but they can save themselves	2
There is danger for the people and evacuation is aggravated (high smokiness, large number of present persons, fast spreading of fire, multi-storey structure, presence of disabled persons – sick persons, old people, children)	3

Table 9. Coefficient of risk for the devices D

Concentration of values	Coefficient D
The contents of the structure are not of high value and have a low tendency to destruction	1
The contents of the structure have value and tendency to destruction	2
The destruction of the value is final and the losses are irreparable (cultural goods and alike), or with their destruction, the existence of the inhabitants is directly endangered.	3

Table 10. Smoke efficiency F

Factors leading to occurrence of smoke	Coefficient F
There is no particular danger for occurrence of smoke and corrosion	1
More than 20% of the total weight of all flammable materials cause smokiness, or release poisonous products from combustion	1.5
More than 50% of the total weight of all flammable materials cause smokiness or release of poisonous products from combustion	2
More than 20% of the total weight of all flammable materials consist of materials that release highly corrosive matters.	2

The obtained values for these two components are plotted on the ordinate and abscissa of the Fire risk decision diagram (Figure 3). Each combination of building fire risk and fire risk of the contents of the building corresponds to a particular point on the diagram. The position of the point can be used to decide whether it is justified to take additional fire protection measures. **In this case zone 1 means that the risk is very low, so preventive measures are sufficient.**

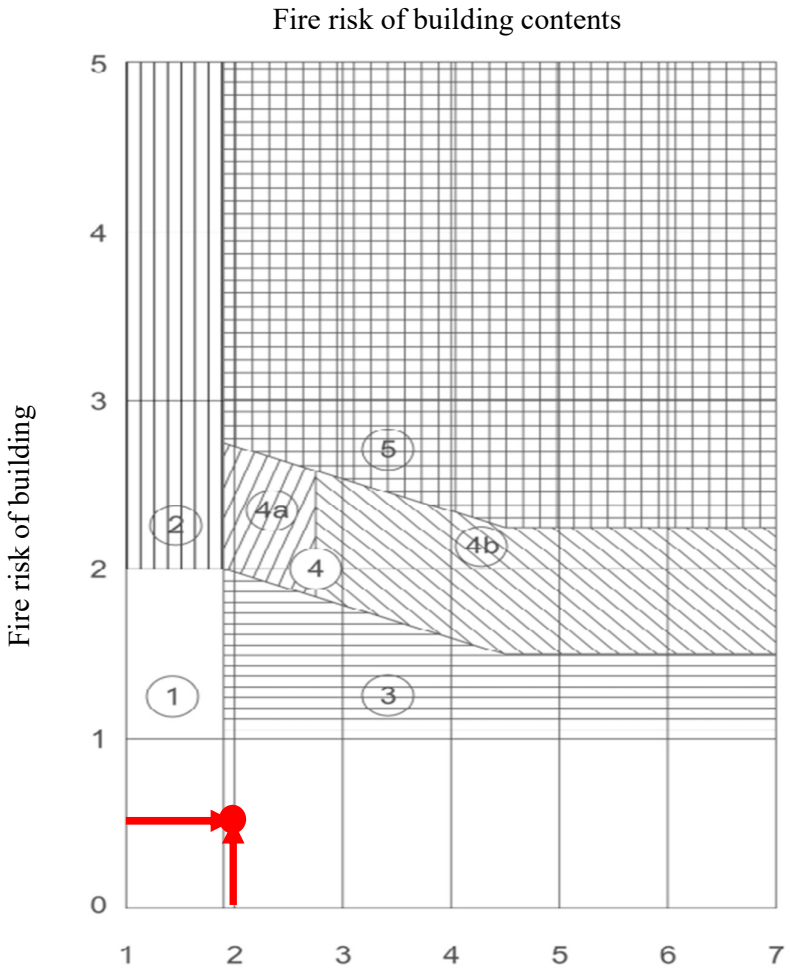


Figure 3. Fire risk decision diagram

2.4. Evacuation time from Faculty

Time of evacuation of school building was calculated by using the program „Pathfinder“ [5]. The building floor plan is presented in Figure 1. The maximum number of employees and students that can be present in the building is N = 130. The farthest room from the evacuation exit from the building is L = 20 m. The width of the exit door which leads directly to a safe place is 1.0 m and is located in the main hall. The total time of evacuation is sum of times for leaving the rooms, moving through the halls and stairs and arriving at the safe place. For example, Figure 4 presents the time of evacuation when occupants are in different rooms.

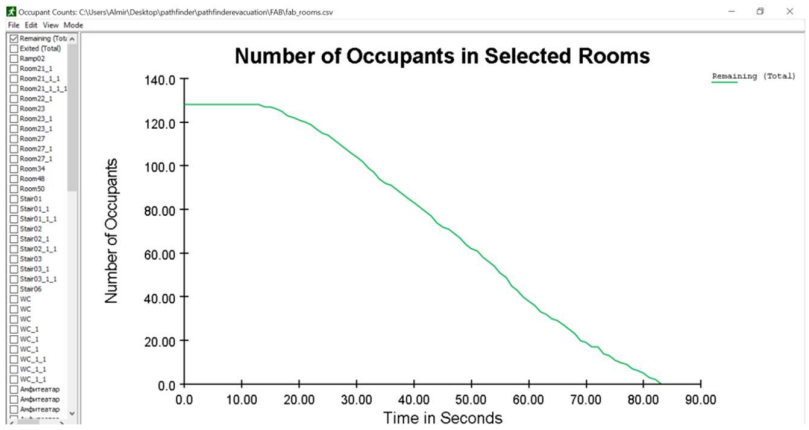


Figure 4. Evacuation time from different rooms

According to the calculations, the total time of evacuation is **t=1.38 min. This time is shorter than the time for the fire brigade to arrive and start extinguishing the fire.**

Conclusion

In accordance with the conducted research, it can be concluded that the Faculty of Business Administration is in very good condition and already fulfil all the necessary measures for protection against fire.

Based on the results obtained, it is recommended to make an evacuation plan in each floor and also to reduce into minimum the flammable materials located in the basement.

The analysis has shown that, for fast and initial, but still sufficiently accurate assessment of the risk pertaining to fire outbreak, one can use quality methods as are the Matrix Method and the Elementary Five-Step Method.

In accordance with the conducted research, compared to these methods, it can be concluded that the application of quantitative methods, as the Euro-alarm Method, is more effective and these methods are used for more detailed analyses in assessing the risk related to fire outbreak in a specific structure.

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