

# Assessing the Risk of Material Damage of Building Construction of High-Rise Rooms Due to Fires and Emergencies

KOVAL Roman<sup>a\*</sup>, YEMELIANENKO Serhii<sup>b</sup>, KUZYK Andrii<sup>c</sup>,  
STARODUB Yuriy<sup>d</sup>

Lviv State University of Life Safety, Kleparivska str., 35, Lviv, Ukraine, 79000

<sup>a</sup>romankoval\_ies@ukr.net, <sup>b</sup>yemelyanenko@ldubgd.edu.ua, <sup>c</sup>andrij\_k@yahoo.com,  
<sup>d</sup>george\_starodub@yahoo.com

**Keywords:** hotel, material damage risks, destruction, fire, risk management, insurance, safety, calculation method, building materials of rooms, hotel construction.

**Abstract.** In recent years, in connection with numerous incidents of fires occurring in hotels, many studies have been conducted on risk management issues, as well as actions in emergencies. Research has often been limited to incident analysis rather than addressing how to manage fire safety to minimize risks and did not sufficiently take into account the features of the construction of the hotel building and the characteristics of materials.

The existing state of management and regulation of material damage risks from fires and emergencies does not fully take into account the approaches and means for their minimization, in particular in hotels. There is an increasing need for the use of assessment methods that will help in the performance of risk management functions.

There is a need to find effective mechanisms for assessing the risks of material damage of building construction and materials of high-rise rooms from fires and emergencies. Fires in public sites on the example of hotels have been taken for research.

There is an increasing need for the use of assessment methods that will help in the performance of material loss risk management functions.

During the period of martial law, the method of assessing material damage to the building presented in the article can be used to assess material damage from destruction and fires for future compensation. With the help of this method, it is possible to estimate probable material damage from fires and emergencies, which will allow them to be used in supervisory and preventive activities and the insurance industry.

Thus, fires in hotels cause significant material damage, and recently, as statistics show, also human losses. In hotels, it is important to ensure the protection of the building, premises and people from fire. Therefore, the issue of assessing fire risks is currently relevant. Fire risk assessment is an important part of fire science and safety engineering.

## 1 Introduction

Like any other structure, hotels are exposed to the risks of fire, but there are certain aspects that complicate their fire safety systems and plans. Firstly, hotels have a high occupancy rate due to the large number of rooms and the large number of guests. In addition, unlike office premises or residential complexes, guests are not familiar with the building and possible evacuation routes. Many hotels also have restaurants - kitchens increase the risk of fire due to open flames, flammable grease traps and storage of flammable materials. With the beginning of the military aggression of the Russian Federation, the risks of fires and emergencies have increased significantly.

Today, Ukraine is undergoing a transformation of approaches regarding the importance of developing the hotel business, because this is one of the effective ways of developing the state economy, because this sector is able to provide the country with foreign exchange earnings, create new jobs and other benefits.

The hotel industry is an important component of the functioning of a dynamically developing state. Hotel service is a key factor that includes a range of services and determines the prospects for the

development of tourism. And in wartime conditions, its functions are significantly expanded and include the function of providing housing for the internally displaced population.

A modern hotel is a multifunctional complex, which includes not only room stock, but also can have conference halls, bars and restaurants, gyms, tennis courts, swimming pools, nightclubs and other entertainment and household facilities. Some rooms can be multifunctional. Hotel complexes belong to objects with a mass stay of people, which sets high requirements for fire safety.

There are very few research focusing on preventive measures. Therefore, it is necessary to pay considerable attention to the study of the management and assessment of hotel fire safety.

It is important to note that the component composition of hotel construction materials can be different depending on many factors, including the geographical location of the hotel, the type of building, the corresponding building standards and other factors.

Regarding the fire safety of building materials, it is important to keep in mind that some construction materials may be more refractory than others. For example, concrete is a material with high fire resistance, while wood and plastic can light up quickly. Therefore, when choosing construction materials for the hotel, you must consider their fire resistance and fire safety.

Fireproofing and other special materials are used to ensure fire safety of hotel construction. Also, to reduce the risk of fire spread, fireproof partitions, doors and windows are used.

## 2 Analysis of Literary Data and Statement of the Problem

A number of domestic and foreign scientists deal with the issues of material damage risks: O. Muzyka, V. Onyshchenko, M. Zaliyev, H. Kozmenko, S. Kravchuk, V. Bazylevych, N. Vnukova, O. Vovchak, S. Osadtsia, O. Zaruba, I. Blank, N. Vnukova, D. Farni, L. Khorin, T. Veihan, Zh. Perar, P. Yokhansen and others. However, the current state of managing and regulating the risks of material damage from fires in hotels does not sufficiently take into account modern approaches and methods of their assessment and minimization.

In addition to the risks of fires or emergencies, the death of people, the risks of material damage are important.

As a result of fires and emergencies, buildings and structures are damaged and become unusable furniture and various equipment.

The component composition of hotel construction materials can be quite different, depending on what specific materials are used for different elements of the building, such as walls, floors, roofs, windows, etc.

Damage assessment requires proper assessment of material risks of construction of the hotel. Assessing the risks of material damage is also relevant in the conditions of martial law. Material damage caused by military actions must be properly assessed. Ukraine plans to compensate for the losses by attracting funds from the aggressor country. According to the latest report within the framework of the joint project of the Ministry of Economy and the Kyiv School of Economics (KSE Institute), as of February 2022, the direct losses of the Ukrainian economy from the damage and destruction of residential and non-residential buildings and infrastructure amount to almost \$195 billion, and the total level of losses is estimated at \$800 billion. The methodology for assessing such losses is general and takes into account the experience of the World Bank in analyzing damage in Syria and Iraq, as well as the recommendations of the leading Ukrainian investment company Dragon Capital [2].

This methodology does not sufficiently take into account the specifics of an individual object by region, building type, and material damage caused by destruction and fire.

The increase in the number of fires and emergencies in hotels makes it necessary to assess the risks of material damage. In the order of the State Property Fund of Ukraine of the Ministry of Regional Development, Construction and Housing and Communal Economy of Ukraine dated 27.08.2012 No. 3379/430 "On approval of the Procedure for determining the cost of reproduction or replacement of land improvements of houses, buildings and structures of multi-story residential construction" the methodology that is used to determine the cost of replacing multi-story residential buildings.

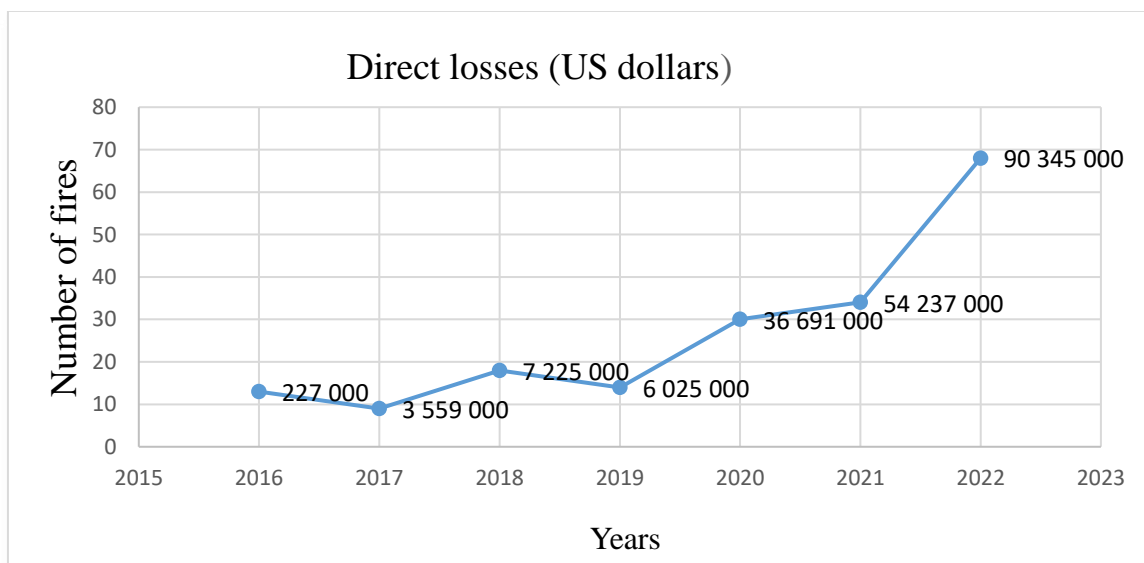
However, it is quite complex and is not used for public buildings, in particular hotels. Since a significant number of people live in hotels for a short period of time, mostly unrelated to each other, it is important to ensure their safe stay.

Hotels have fundamental differences from other economic facilities. On the one hand, the hotel management is interested in creating a certain level of image with the provision of the mode of greatest assistance for the maximum number of guests, and therefore any security devices should not attract the attention of visitors, but, at the same time, provide a sense of personal safety and comfort [3].

In the construction of hotels, different construction materials are used, depending on the specifics of the project, budget, wishes of the customer, design. The main construction materials for hotels include as follows: concrete, brick, glass - to ensure fire safety use fire retardant glass, metal is a strong and wear-resistant material that can be used for the construction of hotels. It is often used to create contemporary and industrial styles, wood can be used as a natural material for hotel construction, which creates a warm and cozy atmosphere. However, it is not resistant to fire and may require more maintenance and replacement. Other materials such as plasterboard, ceramic tile, plastic, stone and others are also used in hotel construction.

Hotels are more than just commercial buildings. Large hotel complexes with their heating and air conditioning systems, ancillary buildings, IT infrastructure and staff accommodation can easily be compared to modern industrial facilities, as the surrounding infrastructure shares many similarities.

According to statistical data, in recent years, there has been an increase in the number of fires and the amount of material damage caused by them, therefore ensuring fire safety and assessing property fire risks in hotels are issues that require detailed study. (Fig. 1).



**Fig. 1.** The number of fires and material damage from them in hotels of Ukraine for the period 2016–2022.

In particular, at the present time, during the period of martial law in the city of Chernihiv, the Russian occupiers bombed the hotel "Ukraine", causing some damage. Therefore, there is a need to find effective mechanisms for assessing damage from military actions and assessing the risks of material damage from fires.

In Ukraine, it has been approved at the state level Resolution of the Cabinet of Ministers of Ukraine No. 342 dated 10.05.2018 "On approval of methods for developing criteria by which the degree of risk from conducting business activities is assessed and the periodicity of planned measures of state supervision (control) is determined, as well as unified forms of acts, which are drawn up based on the results of conducting planned (unplanned) measures of state supervision (control)", where the Methodology for developing criteria for assessing the degree of risk from economic activity is given.

Resolution No. 715 of the Cabinet of Ministers of Ukraine dated September 5, 2018 "On approval of criteria for assessing the degree of risk from economic activity and determining the periodicity of planned state supervision (control) measures in the field of man-made and fire safety by the State Emergency Service" are also defined criteria by which the degree of risk from economic activity is assessed and the frequency of implementation of planned measures of state supervision (control) in the field of man-made and fire safety by the State Emergency Service is determined.

The available criteria take into account: the type of object, the number of people, the conditional height of the object, the presence and scale of possible dangerous events, the class of consequences, the number of violations of legal requirements in recent years. The number of points on a 100-point scale and the degree of risk are determined based on the results of monitoring relevant indicators for the facility.

Further verification of the economic entity is carried out with a frequency that depends on the sum of the points accrued and the degree of risk. But this technique does not apply to public buildings, in particular to hotels, and does not include methods for assessing the risks of material damage from destruction and fires.

### **3 The Purpose and Objectives of the Research**

The purpose of the work is to assess destruction and caused material damage based on risk-oriented approaches and methods, in particular, assessing the risks of material damage from fires for public buildings (for example, hotels).

### **4 Research Materials and Methods**

To assess the risk of material damage from destruction to the building construction of the hotels caused by fires and emergencies, in particular during the martial law, a method is required, which, based on the average values and the minimum amount of data, gives the real value of material damage. The presented method takes into account the cost indicators for the relevant groups of buildings, and also provides opportunities for assessing and forecasting material losses and their compensation due to damage caused by fire or emergencies. We suggest using this method to evaluate not only buildings in a certain area, but also a separate building and its premises.

The basis of the method of assessing material damage in the premises of the building is to establish the ratio between the value of one m<sup>2</sup> of the average statistical premises of the relevant group and other types of premises of various purposes. In the case of hotels, for example, one m<sup>2</sup> of a "luxury" room costs 1.5 times more than one m<sup>2</sup> of an average room in this hotel.

Hotel premises have different purposes (rooms of different classes, hall, corridor, office premises, stores, hairdressers, cafes, bars, etc.). To use this method, you must have a list of premises, their main characteristics and functional purposes.

The risk to life and property is high in hotel buildings due to the high concentration of people and valuables.

Hotels are facilities where security plays a key role. These are mainly high-rise buildings with a large number of living rooms, corridors and halls. In general, hotels also have warehouse and office space. Often, catering establishments that have their own specific premises and equipment are located in the premises of hotel buildings. There may also be industrial premises where laundry is washed and ironed, minor equipment repairs are carried out, inventory is placed. Some hotels have equipped recreation areas (greenhouses, gyms, swimming pools, casinos, saunas, etc.).

Hotels belong to the classes of facilities where security plays a key role. These are multi-story buildings with a large number of rooms and long corridors.

Hotels can be classified according to various parameters (floor space, number of places to stay, degree of fire resistance, type of fire alarm and fire hazard management system). These parameters are dependent on each other, and therefore we propose to take as a basis the combined classification by floor area (Table 1).

**Table 1.** Groups of hotels by floor area and other fire safety indicators

No. of the group	Groups of hotels by floor area	By the number of places to stay	According to the degree of fire resistance [5]	Type of fire hazard notification and management system [4]
1	1–2-storey	small, up to 150	all types	2 or 3
2	3–5- storey	small and medium, 150–400	I, II, III	not lower than 3
3	6–9- storey	medium 150–300	I, II	not lower than
4	10–40-storey	medium and large, 300–400	I, II	not lower than 3, 4, 5
5	More than 40 floors	large, more than 400	I, II	not lower than 4, 5

## 5 Research Results

Hazards are defined as certain negative case scenarios: "when a failure occurs, some damage will result".

In order to turn "danger" into safety, it is necessary to know some acceptable values of risks that can cause a hazard.

Risk assessment is a growing practice in all security-related industries.

Different methods are used to meet the needs of many decision-making processes where it is important not only to know what to do, but more importantly to have a reasonable idea of the state of the cost-benefit balance of proposed actions.

The greatest attention is paid to the state of fire safety in high-rise hotels. For calculations, 4 hotels in the city of Kyiv were used: No. 1 - height 57.5 m (17 floors, 276 rooms), No. 2 - height 65 m (21 floors, 433 rooms), No. 3 - height 66 m (16 floors, 375 rooms) and No. 4 – height 70.55 m (22 floors, 187 rooms).

We will demonstrate the improved method of assessing material damage from fires and emergencies using the example of Hotel No. 1 in Kyiv according to the main six stages:

The first stage involves determining the average value of the cost of one m<sup>2</sup> of the corresponding hotel room according to the formula:

$$G = S_c \cdot B_o, \quad (1)$$

where:  $S_c$  – average area of a hotel room (29 m<sup>2</sup>);  $B_o$  – average cost of a hotel room (as of 2022 in Kyiv, it amounted to UAH 50,240. per m<sup>2</sup>).

At the second stage, it is necessary to calculate the "Coefficient of replacement",  $K_3$ – the ratio that allows you to move from a room in a specific building to an average room taking into account the corresponding group (hotel) and is calculated according to the formula:

$$K_3 = \frac{S_{np} \cdot K_B}{S_c}, \quad (2)$$

where:  $S_{np}$  – the area of a specific room of the investigated object (hotel No. 1);  $K_B$  – the cost coefficient for the corresponding group, which is determined according to tabular data (Table 2);  $S_c$ – average room area.

All hotel premises have a different purpose: residential area, administrative and economic, auxiliary premises, engineering and technical premises. The structure of the premises in hotels is determined by its type, category, dimensions, features of the organization of comfort for guests and working conditions of the staff.

The surrounding area is important for hotel enterprises. It should be sufficient in size to fulfill the production tasks of the accommodation facility, to ensure the necessary recreational, ecological, and aesthetic conditions for hotel guests.

If the premises in the hotel have several purposes (for example, a hotel above a store and a restaurant), then they must be assigned to separate subgroups and the replacement coefficients for each of them must be determined (Table 2).

**Table 2.** Cost coefficient for the corresponding subgroup of premises ( $K_B$ )

Groups of houses	Correlation	Note
Public buildings		
Hostel	1.1	
Hotel – 3 stars	2.8	
Hotel – 5 stars	3.75	
Restaurant	1.8	includes kitchens and refrigerators
Restaurant TOP	2.2	includes kitchens and refrigerators
Store	0.8	Store or one specialized store
Big store	1.4	A large store or a single store
A large store or supermarket		Store or one specialized store (>1000 m <sup>2</sup> )

The third stage is to assign the predicted value of the damage to the building ( $K_{3\delta}$ ). Damage characteristics are general and mandatory for objects and do not depend on their functional purpose. This indicator is determined by the values (tables 3 and 4).

Not all premises of the building that may be damaged by fire are subject to complete restoration, and therefore we can only take into account a certain percentage of the cost of reconstruction of the entire building.

**Table 3.** Amount of fire damage ( $K_{3\delta,n}$ )

The cause of the damage	Characteristics of damages				
	Light	Moderate	Heavy	Severe	Destructive
	0.02	0.10	0.40	0.75	1.00
Fire	Interior smoke damage requiring repainting, restoration and/or re-plastering in the same room. Fire damage to external walls (eg cladding, decorative cladding, drains, etc.)	Interior smoke damage requiring repainting, refinishing and/or recarpeting throughout, windows requiring replacement due to deformed or stained glass. A small fire that did not cause danger to the ceiling. A minor fire that does not cause structural damage to walls and partitions	Windows and window frames require replacement due to melting (metal, wood, or plastic). Moderate fire damage to partitions and ceiling. Fire damage that does not cause the destruction of load-bearing walls	Severe fire damage to the building structure, such as a floor or ceiling failure, causing partial or complete collapse. Fire damage causing the collapse of at least one load-bearing wall, support column or pillar	With complete or almost complete destruction

For example, a hotel after a fire has only minor damage that can be repaired for 10 % of the cost of a fully renovated hotel.

**Table 4.** Amount of damage from destruction ( $K_{36,nc}$ )

The cause of the damage	Characteristics of damages				
	Light	Moderate	Heavy	Severe	Destructive
	0.02	0.10	0.40	0.75	1.00
Emergency	Damage caused to external walls (for example, cladding, decorative cladding, drains, etc.). Damaged antennas, broken windows	Extensive damage to the exterior walls	Destruction, severe damage to at least one outer wall, the core of the steel frame structure	Disintegration of at least one outer wall, frame or partial destruction	With complete or almost complete destruction

At the fourth stage, the damage coefficient is determined, which is determined for "room equivalents" – this is the equivalent number of "medium rooms" that would have to be completely replaced. The damage coefficient for the corresponding group (hotel) is determined by the formula:

$$K = K_3 \cdot K_{36} \tag{3}$$

For example, the equivalent of damage to a room from a fire in case of severe damage for hotel No. 1 will be  $3.13 \times 0.75 = 2.35$  - this is the equivalent amount for the corresponding group, provided that the amount of fire damage ( $K_{36,n}$ ) is 75 % (table 3).

At the fifth stage, the monetary value of the damage to the premises is calculated ( $B$ ).

$$B = K \cdot G \tag{4}$$

If different rooms in the hotel are damaged due to an emergency or fire, then the total cost of damage ( $B_3$ ) is the sum of the costs of damage caused to all rooms, which is calculated according to the formula:

$$B_3 = \sum B_{1,i} + \sum B_{2,j} + \sum B_{3,n} \tag{5}$$

where:  $B_{1,i}$  – the cost of damage to the  $i$ -th room of the hotel room  $i$ ;  $B_{2,j}$  – the cost of damage to the  $j$ -th room of the hotel hall;  $B_{3,n}$  – the cost of damage to the  $n$ -th hotel premises.

With the help of this method, it is possible to estimate probable material damage from fires and emergencies, which will allow them to be used in supervisory and preventive activities and in the insurance industry. As European experience shows, the insurance system encourages hotel owners to ensure safety standards and improve their level, insurance payments can balance fire damage and the costs of their restoration. For insurance needs, it is relevant to have reference books of the values of the main structures and equipment for various groups of objects, which take into account the names of regions, cities, the age of the building and the construction material. Also, when determining the insurance amount for real estate, it is necessary to focus on the total area of the premises and can be used instead of the Cost coefficient for the corresponding building group ( $K_B$ ), correction coefficients that take into account the cost of the room's interior equipment (for example: ordinary, improved, European renovation, exclusive).

To calculate the risks of material damage, it is possible to consider typical scenarios of the occurrence of fires or emergencies, to perform simulations of the processes of their development and liquidation, based on which the cost of material damage can be calculated, which will be the risk of material damage for this hotel [18, 19]. And the risk of material damage from fires or emergencies  $R_{36}$ . (UAH/ fires·year) can be calculated using the formula:

$$R_{36} = P_i \cdot B_i \tag{6}$$

where:  $P_i$  – the probability of the  $i$ -th scenario;  $B_i$  – damage caused;

Therefore, this method can be applied to assess already existing damage or fires (Table 5). However, in order to minimize the risks of material damage from fires, it is important to carry out fire-fighting measures, to maintain the functionality of already installed fire detection and extinguishing systems, therefore, in the future, the authors plan to search for effective fire-fighting measures against fires in hotels on the basis of modern scientific developments.

**Table 5.** The results of calculating the material damage of the building construction of the hotel

Hotel	Risk of material damage (US dollars)
Hotel No. 1	4 245 526
Hotel No. 2	5 600 345
Hotel No. 3	5 876 289
Hotel No. 4	6 120 340

Modern approaches to risk management and assessment are not only mandatory for hotel owners around the world to meet the latest safety standards, but also contribute to improved staff performance and guest satisfaction. Due to the flexibility and possibilities of integration of modern technologies, advanced solutions are available for almost all types of hotels.

## 6 Conclusions

1. The classification of hotels depending on the number of floors and other parameters of fire safety is proposed.

2. It is proposed to use the method of assessing the risks of material damage from fires and emergencies within the building for premises (using the example of a hotel).

3. During martial law, this method of assessing material damage to a building construction can be used to assess material damage from destruction and fire for future compensation.

4. Based on the assessment of damage from fires and emergencies in hotels, taking into account the relevant scenarios, it is possible to assess the risk of material damage for hotels.

5. An algorithm for assessing material risks of construction structures and materials is proposed, an example of a dangerous one is considered, and the necessity is substantiated as one of the ways to improve fire safety management mechanisms of hotels.

## References

- [1] The project «Russia will pay» [Electronic resource] <https://damaged.in.ua/>
- [2] Losses of Ukraine's economy [Electronic resource] <https://kse.ua/.../za-ostannimi-obrahunkami-zagalna-suma.../>
- [3] Law of Ukraine On Approval of the Rules for the Use of Hotels and Similar Means of Accommodation and Provision of Hotel Services [Electronic resource] <https://zakon.rada.gov.ua/laws/show/z0413-04>
- [4] Insurance from fire risks and risks and natural disasters. [Electronic resource] <http://insins.net/insurance-services/114-strahuvannya-ud-vognevih-rizikv-ta-rizikv-stihynih-yavisch.html>
- [5] O.V. Miller, A.I. Kharchuk, P.P. Dubynetska, Fire risks insurance as an alternative to state supervision in the field of fire and technological safety Fire safety: Collection of scientific works, Lviv: LDU BZD, 28 (2016) 96–100.
- [6] O.V. Martsenyuk-Rozarenova, "Property insurance: features, importance and respects of development [Martsenyuk-Rozar'onova O.V. Maynove strakhuvannya: osoblyvosti, znachymist' ta perspektyvy rozvytku]" Financial space, 3 (15) (2014) 147–151.



- 
- [7] S.O. Yemelyanenko, O.M. Shcherbyna, Insurance as a method of managing property security risks. Bulletin of LSULS, 15 2(017) 147–152  
<https://sci.ldubgd.edu.ua/jspui/bitstream/123456789/3909/1/15-19.pdf>
- [8] Y. Klapkiv, Definiitsiia ta osoblyvosti klasyfikatsii katastrofichnykh ryzykiv u teorii strakhuvannia [Definition and features of classification of catastrophic risks in the theory of insurance] Finansovyi prostir- Financial Space, 3(11) (2013) 145–151.
- [9] A.A. Sanitska, D.E. Gogunsky, Sanitska, Labor protection and safety in hotels, Problems and prospects of labor protection development: Proceedings of the IX All-Ukrainian scientific-practical conference of cadets, students, graduate students and associate professors, (2019) 44.
- [10] A.I. Rogovyi, T.M. Efremenko, Formation of the content of the project of organization of security system in hotel business, Bulletin of NTU "KhPI", 1 (2015) 200.
- [11] S.M. Sychevsky, I.M. Rykun, Fire safety of hotel complexes, Actual problems of technical and social sciences in ensuring the activities of the civil defense service: Proceedings of the All-Ukrainian scientific-practical conference, (2014) 44.
- [12] S. Yemelyanenko, A. Ivanusa, R. Yakovchuk, A. Kuzyk, Fire risks of public buildings News of the National Academy of Sciences of the Republic of Kazakhstan, Series of geology and technology sciences, 6 444 (2020) 75–82.
- [13] S. Yemelyanenko, A. Ivanusa, H. Klym, Mechanism of Fire Risk Management in Projects of Safe Operation of Place for Assemblage of People, 1 (2017) 305–308.
- [14] Issues in Risk Science. Natural Hazards Risk Assessment: An Australian Perspective Russell Blong. Benfield Hazard Research Centre, 41–27  
[https://www.preventionweb.net/files/2954\\_nhrauspers.pdf](https://www.preventionweb.net/files/2954_nhrauspers.pdf)
- [15] R.J. Blong, A new Damage Index, Natural Hazards, 30 (2003) 1–23  
<https://link.springer.com/article/10.1023/A:1025018822429>
- [16] E. Hulida, I. Pasnak, O. Koval, A. Tryhuba, Determination of the Critical Time of Fire in the Building and Ensure Successful Evacuation of People, Periodica Polytechnica Civil Engineering, 63(1) (2019) 308–316.
- [17] A. Ivanusa, S. Yemelyanenko, and Z. Ivanusa, Safety-focused Stakeholder Management in Civil Protection Projects, 2019 IEEE 14th International Scientific and Technical Conference on Computer Sciences and Information Technologies (CSIT), (2019) 27–31.