Mechanism of Fire Risk Management in Projects of Safe Operation of Place for Assemblage of People

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***Abstract*—The mechanism of fire risk management at the place for assemblage of people was developed. It is established that individual fire risk human deaths from fire exceeds the permissible value, therefore the additional fire prevention measures at improving the safe operation of the facility have been developed. It is shown that risks of people death on facilities of for assemblage of people largely depend on the duration of limit-permissible values of fire hazards that prevent safe evacuation of people. Practical using of the proposed mechanism of risk management allows to reduce the level of danger to people at operation of place for assemblage of people.**

Keywords*— fire risk management, project of safe operation, place for assemblage of people, mechanism of risk management.

I. Introduction

Provision safety of citizens belong to the priorities of the state policy in the field of civil protection. As declared by State Emergency Service of Ukraine [1,2], a fire occurring in various fields of human activity commits the greatest threat to human life and material damage. The important task is investigation of safety of people in the place for assemblage of people since significant proportion of fires and dead people in their consequent falls in industrial facilities, public buildings.

The main task in this direction is development of working tools to manage project risks. Many leading scientists was engaged this problem. In their work they proposed methodology, principles, methods and models of risk-based approach, which provide solving risk management, resources, finance, timing and quality of projects and programs [3-9]. Such famous scientists as Rak Yu., Zachko O, etc. developed new and improved existing methods, models and mechanisms of rescue services and civil defense system of Ukraine [10-12]. In these works, ways of solving scientific and applied problems of building a methodological basis for security-oriented project management of complex organizational and technical systems on the example of civil protection were represented. A conceptual-categorical apparatus and conception of safety-oriented project management of complex systems were also developed. The system model of security project of building the “Arena Lviv” was proposed that implements methodological approaches to security planning project at the conceptual stage of the life cycle. The approach to model development of life cycle of complex infrastructure projects of regional system that provides formalization of the basic processes of the system was suggested. These provisions enabled the development of product service model of complex safety assessment for infrastructure project of “Lviv” airport.

As was shown early, the risk-based approach is advisable to using for evaluation of fire risk in buildings and public facilities. However, the legislative basis of Ukraine has no methods for fire risk calculations in buildings and human facilities. Therefore, the important scientific works on investigation of the fire risk should be considered [13-15]. In these works, fire risks were studied using event trees (bounce trees). In particular, firstly the method of analysis using the failure trees was developed by J.A. Watson and revealed in the works of Lambert and Fussel.

E.J. Henley and H. Kumamoto made an important contribution to the development of failure trees method. In respect to their direction, failure trees and cause-effect diagram are complex logical structure, construction and quantitative analysis of which requires specialized knowledge of equipment or facility. The main objective of reliability and safety analysis is reducing of risk at accidents and emergencies that caused by human casualties and economic losses polluting. Determination of causal interactions between initial events against people, equipment and environment that lead to failures in the system and search for measures to reduce negative interactions through system redesign or improvements are important in the study of the dangers character to the given object. Causal interactions can be render through failure trees, which are subject to a qualitative and quantitative analysis. The system can be improved to reduce the level of risk after initial list of negative interactions that lead to dangerous consequences. However, in their scientific studies development of the working tools for risk management at the facilities occupancy characteristics or factors influence on the value of fire risk are not considered. Taking into account all above stated, performance of scientific research directed on managing fire risks in projects of safe operation of facilities mass occupancy of people is needed. The aim of this work is development of risk management tools and mechanism for fire facilities occupancy.

II. RESULTS AND DISCUSSION

The first risk calculation were performed in the USA. Obtained results were risk assessment of nuclear power plants and scientific substantiation proposals to their reducing. In Poland, the risk value is interpreted as a measure of the threat, which expresses a potential danger. L. Simak treats risk as quantitative and qualitative expression of threats stage and degree of threat. J. Mikolaj indicates that the risk is uncertainty and uncertainty as well as element of human action in a particular environment. The risk is associated with human activity, and uncertainty - with state of environment or limited system.

One of the methods to determination of calculated values of fire risk in buildings of various classes of functional fire danger firstly was used to calculation of fire risk in building but later was canceled for these objects inexplicably. The behavior of fire and danger depends not as the purpose of the object, but also from their design and other features. Fire risk assessment is carried out by comparing the calculated values of fire risk with established normative values.

Determination of fire risk values is to calculate the individual fire risk for residents, staff and visitors to the building. Quantify the individual risk of fire is the frequency influence of condition on people located in a building. The frequency of influence is determined for fire situation characterized by the greatest danger to the life and health of people in the building. The disadvantage of the methodology is their quite complication. This methodic does not take into account all the architectural and technical features of buildings and their spatial arrangement, without which it is impossible to properly assess fire risks. Therefore, application of such technique needs improvement to determine the time of evacuation, taking into account the time following the fire and rescue units and the onset of limiting concentrations fire hazard.

Specialized programs such as “SITIS: Floutek VD”, “SITIS: Block”, “SITIS: VIM”, “SITIS: Spring”, and “EPOC: Indiline 1.01” were developed by “SITIS” Company [16] for calculation of risk based on proposed methods. These programs can be used to determination of fire risk in buildings of different classes of functional fire hazard. The PyroSim program contains a user graphical interface for modeling the dynamics of fire hazards by field-based Fire Dynamics Simulator (FDS) [17]. The FDS program implements estimated hydrodynamic model mass transfer heat during combustion. FDS solves the Navier-Stokes equations for low-temperature-dependent flow. Particular attention program is paid on smoke spread and heat during a fire. The Smokeview program [18] is reproduces the results of FDS as animation imagines. The program has the ability to visually simulate fire and smoke. Three-dimensional images of the physical model provides an estimate visibility within the depicted space.

The CFAST model [15] is designed to assess the dynamics of fire hazards in residential, public and industrial buildings. This model can be also used to determine the design parameters of fire such as smoke natural or artificial ventilation, fire alarm. For calculation CFAST uses two-zone model that is more efficient than integrated, simulates fires in buildings and determining the time after the onset of dangerous factors to set the required time for a fire-rescue units to place a call and required the evacuation, which will provide security for the people.

Thus, the mechanism to control fire risk of place for assemblage of people (Fig. 1) was developed based on data analysis of scientific developments Ukrainian and International scientists from the field of risk management in projects of various kinds of human activity.

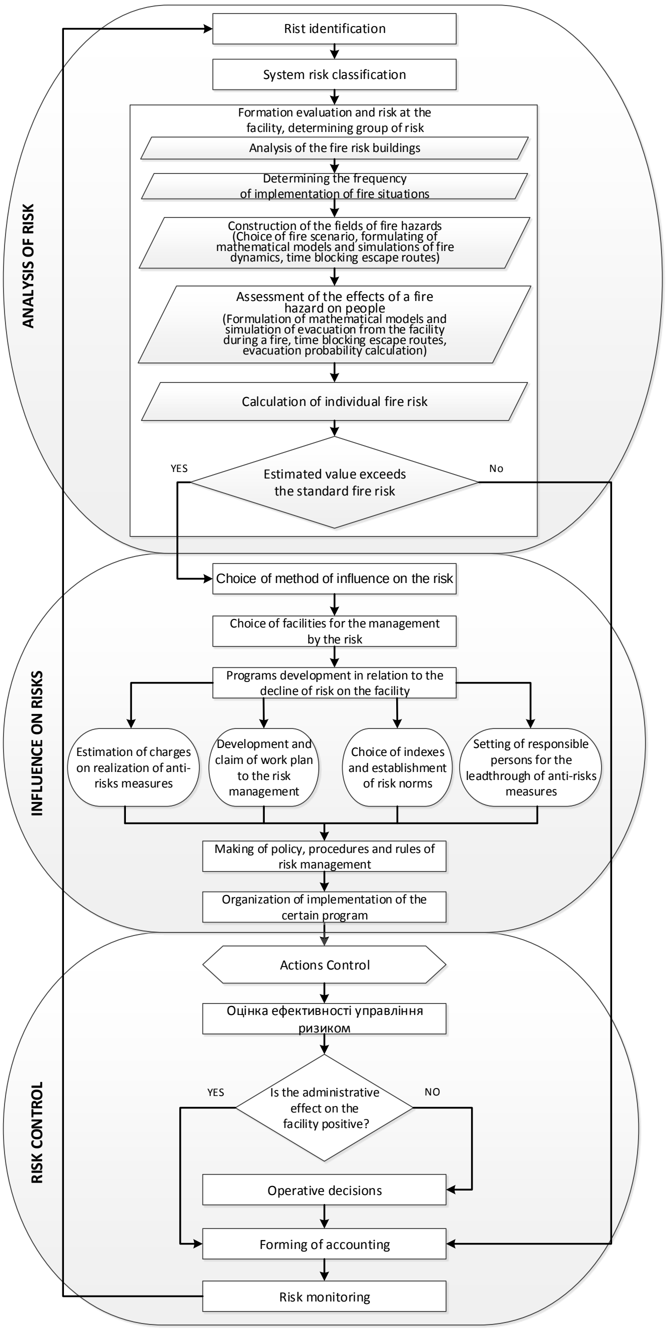

Fig. 1. Mechanism of the fire risk at the of place for assemblage of people

This mechanism adapted to the existing legal framework of Ukraine, which regulates activities in the field of security of people and uses modern working tools to minimize project risks. In this work the building of Lviv National Palace of Aesthetic Education of Youth was selected for the study as of place for assemblage of people. This building is public entertainment facilities characterized by simultaneous presence of large amount of people. So developed fire risk management mechanism will be used to minimization during operation the selected object.

In respect to the proposed mechanism first steps is risk identification at the facility and their classification. Later risk estimation and formation at the facility are performed. In this stage risk groups are defined. We focus our attention on the fire risk. For its evaluation in the studied building the limit values for possible fire hazards were determined.

It should be noted that the most dangerous place in the building of Lviv National Palace of Aesthetic Education of Youth at fire is the auditorium on the 2-nd floor. In the event of a fire at the time of arrival of the first units of a fire spreads and reaches about of 100 m^2. The 2-nd and 3-rd floors is heavily smoky, fire will spread threatening adjacent and located above premise. Prediction of fire is one of the necessary steps to minimize losses during the fire. Therefore, it is necessary to know the most dangerous scenarios emergence and development of fires.

After analyzing the space-planning decisions and fire load space the conclusion can be noted that combustible materials, furniture, equipment and decoration can be way of fire spread. Organizing the evacuation and rescue of people is a priority task with the rapid spread of smoke through the corridors and the stairwell on the subject. It is therefore necessary to determine how much time will come concentration of limit fire hazards in the building and come time when the evacuation of people will be impossible without respiratory protection.

Using CFAST program the calculation of concentrations limit the onset of fire hazard for facilities mass occupancy of people was performed. Obtained results is shown in Fig. 2.

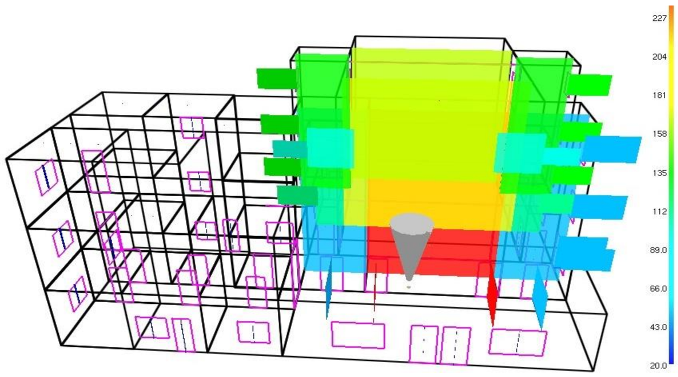

Fig. 2. The visual model of the time of fire hazards in the in the place for assemblage of people

After calculation the following conclusions were revealed: (1) average-volume temperature (see. Fig. 3 schedule “T”) on the stage will be of 260 °C, in the hall No 1 temperature will be of 209 °C (after 3.8 min in the upper part premises and 7 min in the lower part of the room) and in the hall No will be of 189 °C (4.2 min through the top of the room and 7.7 min in the lower part); (2) oxygen shortage of people in the area of the acting stage felt already after 6.5 min, in the auditorium No 1 – about 7 min, in the hall No 2 - after 7.2 min, in the stairway No 4 and No 5 - 9.5 min, and in the corridors No 2 and No 3 - 10 min; (3) lack of visibility will comes: at the top of the stage after 15 s and 2.1 min at the bottom of the room; in the hall No 1 - in the upper part after 16 s and 2.5 min at the bottom of the room; in the hall No 2 - in the upper part after 17 s and 2.6 min - in the lower part of the room; in the corridor No 2 and No 3 in the lower part through 2.9 min; on the stairway No 4 and No 5 through the top of the 2.1 min and 2.9 min in the lower part (see. Fig. 3).

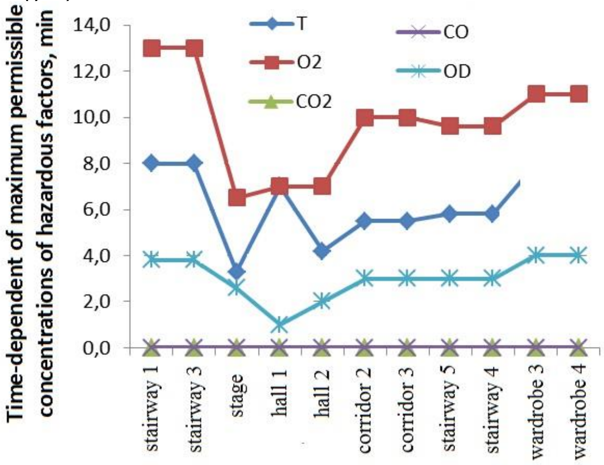

Fig. 3. Time-dependent of maximum permissible concentrations of hazardous factors of temperature, lack of visibility in a fire indoors in the place for assemblage of people

After a comparative analysis of the above-mentioned results, it is established that the lack of visibility for people in building at risk of fire most likely come as conduct evacuation of people from the halls No 1 and No 2 necessary to 2.5 min, walk through the No 4 and No 5 stairways and No 2 and No 3 corridors necessary of 2.9 min.

The calculation of individual fire risk in the place for assemblage of people was performed by the equation [19]:

$$Q_v = Q_{vp}(1-K_{ap})P_{pr}(1-P_e)(1-K_{p.z.}) \,, \tag{1}$$

where: Qv - the frequency of fire in the building, K_{ap} – coefficient considering compliance with regulations concerning automatic fire; P_{PR} - the probability presence of people in the building; P_e - the probability evacuation of people from the building; $K_{p.z.}$ – coefficient for the compliance with fire protection aimed at ensuring safe evacuation during a fire with regulatory requirements for fire safety.

The frequency of fires in the facility of mass occupancy of people Q_{vp} is $6{,}9{\cdot}10^{-3}$. As studied facility not be equipped with automatic fire-fighting, then take C_{ap} as 0.9. The probability of the people presence in a building defined by the equation:

$$P_{pr} = t_{func} / 24 \,, \tag{2}$$

where t_{func} – time functionality of the facility (hours). In our case P_{pr} = 9 / 24 =0,375. Then the probability evacuation was calculated using the equation [19]:

$$P_e = \begin{cases} \frac{0.8 \cdot t_{bl} - t_r}{t_{pv}} \text{ if } t_p < 0.8 \cdot t_{bl} < t + t_{pv} \text{ and } t_{sk} \le 6 \text{ min} \\ 0.999, \text{ if } t_p + t_{pv} \le 0.8 \cdot t_{bl} \text{ and } t_{sk} \le 6 \text{ min} \\ 0.000, \text{ if } t_p \ge 0.8 \cdot t_{bl} \text{ or } t_{sk} > 6 \text{ min} \end{cases}, \quad (3)$$

where t_{bl} - time blocking emergency exits if calculated in the previous section block staircases 4 and 5, come in 2.9 min. In this case, the calculation evacuation time t_p is 4,67 min, start the evacuation for buildings equipped with warning system and evacuation t_{pe} is 3 min. Since the human traffic flow D does not exceed the value of 0.9 for all groups, while crowds t_{sk} = 0 min ≤ 3 min. So, t_p = 4.67 min ≥ 0.8 t_{bl} = 0.8·2.9 = 2.32 min, R_e = 0.000 by the equation (3). Coefficient which taking into account compliance with fire protection aimed at ensuring safe evacuation during a fire was calculated using the equation [19]:

$$K_{p.z.} = 1 - (1 - K_{obn} \cdot K_{sowe})(1 - K_{obn} K_{pdz}), \quad (4)$$

where K_{obn} – coefficient for the compliance with the fire alarm system; K_{sowe} - coefficient for the compliance warning systems and evacuation; K_{pdz} - coefficient for the compliance system to protect smoky. Using proposed method K_{obn} = 0.8 K_{sowe} = 0.8, and as smoke protection is absent, then K_{pdz} = 0. Thus, $K_{p.z.}$ = 0.64. Finally, using (1) it was determined that $Q_v = 9.3 \cdot 10^{-5}$. This value exceeds regulatory risk value $Q_{vn} = 10^{-6}$. This indicates that there is need to move to the next stage of mechanism for fire risk management ("Effect on Risk" in the Fig. 1). Later the steps listed in this mechanism are necessary to perform. Implementation of this and the next stages of risk management mechanism does not require detailed consideration because it contains known procedure studying project management. It is advisable to pay attention to the implementation anti-risk measures noted in the mechanism: (1) to reduce the impact of fire hazards for people to design a fire curtain on the stage; (2) process stage refractory materials; (3) to timely and safe evacuation of people from buildings to simplify space planning solutions in the design stage of these objects or their reconstruction; (4) perform ongoing training of personnel and familiarize the audience with the rules of conduct at fire; (5) equip facilities with highest probability of fire automatic installation of fire alarm and fighting.

III. CONCLUSIONS

An information analysis of research in the field of risk management practices projects safe operation of occupancy and synthesis of modern working tools of this area made it possible to develop an effective mechanism for managing fire risks at the of place for assemblage of people. It is established, that individual fire risk human deaths from the fire at objects of mass stay of people (in particular, on example of Lviv National Palace of Aesthetic Education of Youth) exceeds the permissible value, as developed additional fire prevention measures aimed at improving the safe operation of the facility. Analysis of the fire risk assessment calculations was shown that the risk of human death from fire is largely dependent on the duration of the onset of maximum permissible values of fire hazards that prevent safe evacuation of people. Practical using of the proposed mechanism of fire risk management enables to reduce the hazards for people to an acceptable level in the operation of place for assemblage of people.

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