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Analysis of the Development of Methods for Identifying and Assessing Fire Hazards

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Abstract:

Science based approaches are necessary to be able to identify and assess fire risks to perform fire safety and emergency prevention. Within modern fire protection systems, hazard, risk and safety together represent the theoretical foundation for decision making and for the minimization of losses in both industrial facilities and living areas. Nonetheless, also scientific and regulatory sources show inconsistent and sometimes interchangeable definitions of these terms, which is detrimental to the accuracy of fire risk assessment and to the implementation of management measures. This study analyses and compares definitions of hazard, risk and safety in major scientific literature and normative documents, in order to systematise these definitions into a logical conceptual chain. Hazard, safety, and risk demonstrate that hazard stands for the potential for harmful effect, safety indicates the protected state of the object or system and risk represents a measurable quantitative characteristic of the likelihood of the hazardous event and its expected consequences. It is shown that risk is a variable, context dependent quantity that can be influenced by technical, engineering, economic and organizational actions in ways that equilibrate or mitigate risk to tolerable levels. The results assume that it is impossible to achieve complete safety in practice, but that a scientifically based risk assessment and management will allow the society to accept the observed safety level. This proposed conceptual framework provides a methodological foundation for the development of fire risk assessment and can be used to improve fire safety management both in industrial as well as inhabited areas.

Keywords: fire hazard, hazard, risk, safety, risk assessment, risk management, emergency situations, fire safety

Introduction

The success of preventing emergency situations, eliminating those that have occurred, including performing авария rescue operations at the required level, and ensuring fire safety largely depends on the scientific justification of these activities. This, in turn, requires a theoretical analysis of practice related to emergency situations [1]. From this point of view, in order to ensure the safety of the protected object (system), it is first necessary to study resistance to possible hazards. For example, studies conducted on problematic issues of ensuring fire safety of industrial facilities and residential settlements made it possible to clarify key concepts such as hazard and safety, which require clear definitions.

It should be specifically emphasized that at present, due to the fact that the concepts of hazard and safety are combined within them, constant debates are being conducted among specialists around the concept of "risk," which forms the triad "hazard (опасность) – risk (риск) – safety (безопасность)."

To better understand the issue, it is appropriate to consider these concepts and their definitions in more detail [2].

In the manual prepared by Russian scientists entitled "Fundamentals of Risk Analysis and Management in Natural and Technogenic Spheres," the following definition is given: "Hazard (опасность) is a property of the environment surrounding a person that has the ability to create negative impacts capable of leading to adverse consequences for a person and (or) the environment."

Or: "Hazard (опасность) is a property of the environment surrounding a person that has the ability to create negative impacts capable of leading to adverse consequences for a person and (or) the environment."

In the terminological dictionary "Civil Defense" published in Russia, the following definition is given: "Hazard is the possibility of causing harm to an individual, society, or the state, causing property (material), physical, or psychological (moral) damage [3]. Hazard, along with resistance, risk, and threat, is one of the main concepts of national security, and in their hierarchy it occupies a place between risk and threat. According to the scale and extent of possible negative consequences, hazards can be global, regional, national, local, or private."

As for the concept of "safety" (безопасность), most specialists have formed a common opinion about it. The definition of the concept of "safety" (безопасность) is given in the terminological dictionary "Civil Defense": "Safety is the state of protection of the vital interests of the individual, society, and the state from internal and external threats. Safety, along with a person's need for food, water, clothing, shelter, and information, is one of their most important needs [4]. This general scientific category manifests itself as a form of expressing the totality of the vitality and stability of various objects of the world in specific areas such as internal and external policy, defense, economy, ecology, social policy, healthcare, informatics, technology, and others."

Methodology.

This study employs a theoretical and analytical methodology to construct a systematic framework for recognizing and evaluating the fire risk. Data. The research is based directly on the review and comparative analysis of spectral publications, authoritative legal documents, terminological dictionaries and international standards for fire hazard, energy failure and risk management. An emphasis is put on the use of standards in the field of natural and technogenic systems — both definitions and interpretations of hazard, risk, and safety are considered from authoritative sources [5]. This analysis and comparison reveals the interpretation of the definitions and conceptual approaches, illustrating the similarities, differences as well as contradictions between them. Through the logical analysis and generalization methods, these concepts are systematized into a single theoretical model that expresses the relationship of "hazard risk safety." To be methodologically consistent qualitative analysis is also paired with some quantitative elements in that they give consideration

to how risks can be quantified, compared and reduced to an acceptable level. In addition, the study uses abstraction to simplify these fire hazards into low-level (essential) and high-level (secondary) characteristics to enable identification of key properties that go into risk formation more easily. Normative comparison is used to bring scientific interpretations in line with regulatory requirements used in practice for fire safety [6]. Consequently, the methodology is conducive to creating some common conceptual basis for fire risk qualification and management for both industrial plants and urban areas. This method also makes sure that the results are based on an existing theory which can be applicable to apply on practical fire safety systems and emergency prevention activities.

Result and Discussion.

Regarding the definition of "risk" (риск), there is currently no single opinion among specialists and scientists. In the above mentioned "Civil Defense" dictionary, the definition of the concept of "risk" (риск) and eight types of derivatives from it are presented, for example [7]:

1. "Risk" (риск) is the probable danger of some failure that has arisen in connection with the actions being performed, as well as the actions themselves, the implementation of which is associated with such danger.
2. "Individual risk" (риск индивидуальный) is the probability or frequency of the occurrence of damaging effects of a certain type arising as a result of the manifestation of specific hazards.
3. "Acceptable risk" (риск приемлемый) is a level of risk recognized as justified from the point of view of economic, social, and environmental factors.
4. "Natural risk" (риск природный) is the expected socio economic damage resulting from the probable manifestation of a hazardous natural process or phenomenon.
5. "Risk of occurrence of sources of emergency situations" (риск возникновения источников чрезвычайных ситуаций) is the probability (frequency) of the occurrence of an emergency source with established parameters of damaging factors within a certain time interval.
6. "Risk of occurrence of an emergency situation" (риск возникновения чрезвычайной ситуации) is the probability of occurrence or recurrence of an emergency source determined by relevant risk indicators.
7. "Natural risk" (риск природный) is the expected socio economic damage resulting from the probable manifestation of a hazardous natural process or phenomenon, expressed in the number of deaths, injuries, and the value of damaged personal property and objects of economic activity [8].
8. "Social risk" (риск социальный) is the probability of negative events or their recurrence, characterized by injuries to a certain number of people exposed to damaging effects during the manifestation of relevant hazards.

Based on the above, it is possible to draw certain conclusions and generalizations regarding the definitions that interest us.

First, hazard (опасность) is the probability of causing damage to the protected object, and at the same time it is a specific property of the environment.

Second, safety (безопасность) is the state in which the protected object is protected from various types of hazards.

Third, risk (риск) is the probable danger of an unfavorable event, the probability of occurrence or recurrence of damaging factors, the expected damage, the probability of harm to life and health, the quantitative measure of hazard, the probability of undesirable consequences, the probable danger of events accompanied by damage, the probable danger and the measure of its consequences, and the probability of occurrence of a hazardous event [9]. Some degree of clarity has been introduced into the concept of safety, and it is defined as the state of protection of the protected object from any hazard or threat.

However, the concepts of hazard and risk have not yet been fully clarified. Often, hazard and risk are used as synonyms, which is due to the fact that one is usually expressed through the other. At the same time, most specialists tend to consider risk as the product of the probability of a hazardous event and the damage resulting from it.

In 1997, scientists of the Academy of the State Fire Service of the Ministry of Emergency Situations of Russia, including N.N. Brushlinsky, S.V. Tsokolov, E.A. Klepko, and others, published a scientific work on the problematic issues mentioned above, in which they proposed their views on this issue, which were later further improved, supplemented, and clarified several times [10].

Thus, in their scientific works the following definition is given: "Hazard (опасность) is any phenomenon of any nature (physical, chemical, biological, economic, social, etc.) that can cause damage to society, the environment, or any protected object."

Hazards usually have a potential nature and do not always manifest themselves in the form of a threat. N.N. Brushlinsky, S.V. Tsokolov, and E.A. Klepko provide the following definition: "Risk (риск) is a quantitative characteristic of a specific hazard and the probability of its consequences, usually measured in relevant units."

Any hazard is characterized by a large number of risks that determine various aspects and parameters of this hazard [11]. For example, the duration of its manifestation, as well as the nature and magnitude of the consequences of the hazard.

Risk, depending on various situations and factors, can change its essence, that is, it is prone to certain changes. Therefore, by determining the role of various factors affecting the level of risk, it is possible to exert targeted influence to mitigate the negative impact of any hazard, that is, risk can be managed.

Thus, "Risk management (Управление риском) is the development and implementation of a set of measures (technical engineering, economic, social, and other types) that makes it possible to reduce the risk content of a certain risk to an acceptable (permissible) level" [12].

It is clear that today it is impossible to eliminate all risks completely; it is only possible, through targeted actions, to reduce them at this stage of development to a level acceptable to society.

Based on the above, Professor N.N. Brushlinsky and his students proposed the following definition: "Safety (безопасность) is such a state of the protected object (system) in which the content of all risks does not exceed their permissible level" (see Table 1.1).

Table 1.1

Basic concepts of the theory of risk and safety

Concepts	**Definitions of the main concepts**	Notation
Hazard	Any phenomena of any nature (physical, chemical, biological, economic, social, and others) that may cause harm to society, the environment, or any protected object	A, B, C ...
Risk	The possibility of occurrence of a specific hazard, or a quantitative characteristic (measure) of its consequences, usually measured in relevant units	$R_A, R_B, R_C, \ldots$
Risk management	Development of a set of measures (technical engineering, economic, social, and others) that makes it possible to reduce the level of a specific risk to an acceptable level **R***	$R_i \leq R_i^*$ $(i = A, B, C, \ldots)$
Safety	A state of the protected object (system) in which the level of all risks does not exceed the permissible level	$R_A^*, R_B^*, R_C^*, \ldots$

The definition of "safety" implies that, at present, it is impossible to achieve complete safety from threats, and since hazard does not exist in an explicit form, it is possible to consider a system (protected object) safe when it is no longer possible to ensure a further reduction of hazard. Only by taking this condition into account can we speak about safety in terms of the "state of safety" of the protected object, since absolute safety cannot exist [13]. According to the information presented above, the algorithm for ensuring the safety of a

system (protected object) includes identifying and assessing the risks that may pose a hazard to the protected object, and developing appropriate management decisions in order to reduce the risk to an acceptable level.

According to the authors, in this way a logical chain of the hierarchy of the basic concepts of risk and safety theory is formed, which defines the triad "Hazard – Risk – Safety," where "risk management" is considered an additional concept.

At the same time, the concepts such as threat, opposition, and hazard are synonymous and differ from each other only in their specific semantic content; they are characterized by a certain set of risks, and by reducing their values, an acceptable level of safety of the system (protected object) is achieved [14]. The algorithm for ensuring the safety of any system (protected object) is clearly presented (see Figure 1.1).

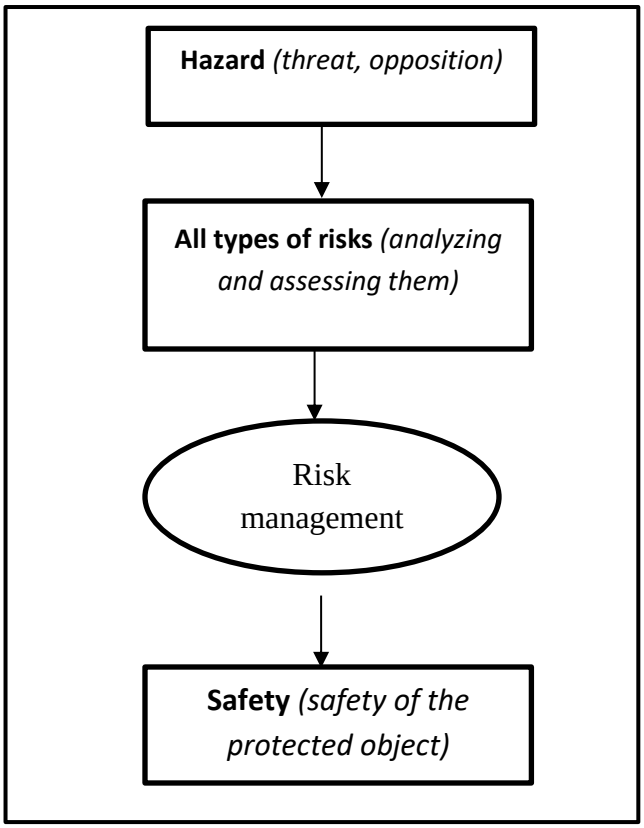

Figure 1.1. The "Hazard – Risk – Safety" triad

Various external and internal hazards may affect any protected object. At the same time, each hazard is characterized by a large number of risks that assess different aspects and indicators of these hazards [15]. This set of risks corresponding to a specific type of hazard may be referred to as a complex risk.

CONCLUSION

Within this approach, the issues of identifying and assessing fire hazards were broadly covered from a scientific and theoretical perspective. During the research process, the essence of the concepts "hazard," "risk," and "safety" was analyzed based on various sources, and their interrelationship was revealed. It was determined that, in ensuring fire safety, it is important to assess hazards not only qualitatively but also through quantitative indicators. In addition, it was substantiated that the concept of risk management is an integral part of the fire safety assurance system. It was shown that the safety level of a protected object can be increased through the comprehensive

application of technical, engineering, economic, and organizational measures aimed at reducing risk to an acceptable level. The conducted analyses indicate that achieving absolute safety is practically impossible; however, by assessing and managing risks through scientifically grounded methods, it is possible to ensure a level of safety acceptable to society. The theoretical conclusions and generalizations presented in the article are of significant scientific and practical value for application in ensuring fire safety in industrial facilities and residential areas.

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