# RISK ASSESSMENT FOR CRITICAL INFRASTRUCTURE IN THE CONDITIONS OF UKRAINE

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**Abstract:** In the article the character of changes in natural and man-made threats for critical infrastructure in the conditions of Ukraine are investigated. Risk assessment for critical infrastructure from emergency situations in Ukraine with regard to the European Union approach is provided. Priorities for risk reduction of emergencies of natural and man-made origin for critical infrastructure protection in Ukraine are recommended.

**Keywords:** critical infrastructure; risk; threats; likelihood; emergency situations; consequences, priorities.

## 1 INTRODUCTION

The operation of numerous mining, chemical, energy companies, a large number of industrial and urban agglomerations and the high population density in them predetermine the increase of emergencies situations (ES) with large negative consequences due to the threat of damage and destruction of critical infrastructure objects (CI). Among such facilities, a certain threat comes from the spatially distributed railways, oil and gas pipelines, bridges, main electricity grids, which safe operation are of primary importance for the socio-economic development of Ukraine.

The critical infrastructure of Ukraine is systems and resources, physical or virtual, which are providing functions and services whose violation may lead to significant negative consequences for the life of the society, socio-economic development of the country and the provision of national security [1].

In accordance with the Code of Civil Protection of Ukraine, an emergency situation is the situation in a separate territory characterized by violation of normal living conditions of the population, caused by a disaster, an accident, a fire, a natural disaster, an epidemic, an epizootic or other dangerous event that has led (may lead) to a threat to life or health of the population, a large number of deaths and injuries, causing significant material damage as well as the impossibility of inhabiting the population in such territory [2].

The threat is considered as a dangerous phenomenon, substance, human activity or condition, which may lead to social and economic losses, loss of life, injury or other health consequences of the population, loss of property, livelihoods and services, environmental damage [3].

In the publication, the risk is considered as a combination of the negative effects of the event or the threat and the likelihood of its occurrence associated with it [4].

## 2 ANALYSIS OF RECENT RESEARCH AND PUBLICATIONS

The study of the main trends and nature of changes in emergencies of natural and man-made origin in the world convinces that there is a growing risk of their occurrence [5]. The current programs and reports of the UN and the World Bank on the consequences of natural disasters and man-made disasters in recent years show a significant increase in economic losses from them [5; 6]. The main approaches to assessing the risk of emergencies of different origins are researched in Ukraine [7; 8] and the world [9; 10].

The analysis showed an increase in the threat of reducing the level of safety of numerous critical infrastructure objects in Ukraine as a result of overtime exploitation of structures, equipment and engineering networks which operating on the verge of exhaustion of their resource and forming serious risks of emergencies of natural and man-made nature for the safety of critical infrastructure operation [11, 12].

In addition, in the conditions of the military conflict in the Donbass, due to the destruction of many industrial and residential buildings as a result of hostilities, there is an increase in the risks of the emergence of man-made industrial origin. Military destruction and damage to many critical infrastructure objects, which can include water treatment plants, chemical plants and agricultural enterprises, poses a serious threat to the population and the environment.

Research in the area of prevention and counteraction to threats of different genesis suggests that the state system of protection of population from natural and man-made ES requires the introduction of a risk-based approach for the effective prevention and reduction of the risk of disasters of various origins for critical infrastructure objects [13; 14].

It should also be considered that the negative nature of changes in environmental and man-made threats that occurs due to pollution of river basins and underground waters, the destruction of landscapes and objects of the nature reserve fund, significantly reduces the level of safety of life of the population in the zone of military conflict in the eastern Ukraine, as well in other territories of Donetsk and Luhansk oblasts, ecologically connected with it.

Significant threat of emergencies of natural and man-made origin comes from the presence in the territory of Luhansk and Donetsk regions of a large number of flooded and semi-flooded mines, which have a permanent hydraulic connection with the

existing mines. The unsatisfactory ecological state of coal mining regions, especially Donbass, is complicated by the high concentration of metallurgical and chemical enterprises, which increases the technogenic load on the environment and creates real threats to the health of the population.

The goal of the article is to analyze the changes of actual threats of natural and man-made nature for critical infrastructure in Ukraine, and on this basis to conduct risk assessments for critical infrastructure with the methodology used in the European Union.

## 3 PRESENTATION OF THE MAIN RESEARCH MATERIAL

During 2016, there were 149 emergencies in Ukraine, of which 89 were of a natural origin, 56 were man-made (Table 1). As a result of these events, 171 people died and 1856 people were injured.

**Table 1** Characteristics of natural and man-made emergency situations in Ukraine in 2015-2016

| Emergency situations | | | Threats for population | | | |
|---|---|---|---|---|---|---|
| Type | Amount of ES | | Died | | Injured | |
| | 2015 | 2016 | 2015 | 2016 | 2015 | 2016 |
| **Emergency situations of man-made origin** | | | | | | |
| Accidents or catastrophes in transport | 14 | 11 | 53 | 33 | 74 | 128 |
| Fires, explosions | 40 | 36 | 103 | 116 | 59 | 35 |
| *Including in buildings or constructions of residential purposes* | *30* | *29* | *85* | *100* | *6* | *11* |
| The presence of harmful and radioactive substances exceeding The maximum permissible concentrations in the environment | 1 | | 0 | 0 | 0 | 0 |
| Sudden destruction of buildings and structures | 2 | 4 | 0 | 3 | 0 | 2 |
| Crashes in life support systems | 5 | 4 | 0 | 0 | 0 | 0 |
| Accidents in oil and gas industrial complex systems | 1 | 1 | 0 | 0 | 0 | 0 |
| ***Total*** | ***63*** | ***56*** | ***156*** | ***152*** | ***133*** | ***165*** |
| **Emergency situations of a natural origin** | | | | | | |
| Geological ES | 2 | 1 | 0 | 0 | 0 | 0 |
| Meteorological ES | 2 | 6 | 0 | 4 | 7 | 13 |
| Hydrological ES of surface waters | 1 | | 0 | 0 | 0 | 0 |
| Related to fires in natural ecological systems | 13 | 4 | 0 | 0 | 0 | 1 |
| Medical-biological ES | 59 | 78 | 22 | 15 | 690 | 1677 |
| ***Total*** | ***77*** | ***89*** | ***22*** | ***19*** | ***697*** | ***1691*** |

Source: [15].

Despite the fact that in comparison with 2015, there was a certain decrease in the number of emergencies of an industrial nature for all types, in 2016 there was an increase of 17 % in the number of deaths in the emergencies associated with fires (explosions) in buildings and structures for residential use, as well as an increase of 72 % of the number of victims as a result of ES in road transport.

In spite of a certain decrease in the number of emergencies of the state level in 2016, the level of risks of natural and man-made disasters and the risks of losses from them remains rather high for most regions of Ukraine. Thus, the largest number of emergencies (14) during 2016 was recorded in the Odessa region. In the Volyn, Mykolaiv and Poltava regions there were 10 ES, in Dnipropetrovsk, Zhytomyr and Chernihiv regions - 8, respectively, in Sumy, Chernivtsi regions and in Kyiv, 7 emergencies were registered.

Among the main reasons for the emergence of natural and man-made disasters in Ukraine in 2016 are non-compliance with the rules of fire safety; ignoring requirements of the rules of the traffic; violation of sanitary and hygienic norms; reduction of control over the implementation of anti-epidemic measures; outdated fixed assets and the state of emergency of a large part of the utilities networks; abnormal manifestations of atmospheric processes [15].

In the first quarter of 2017, 48 ES were registered in Ukraine, 14 of which were man-made and 33 were natural and one of social character [16]. During these events, 47 people died and 261 injured. Compared to the same period in 2016, the total number of ES in 2017 increased by 71.4 %, while the number of ES of anthropogenic nature remained unchanged, and the number of ES of a natural origin increased more than twice, which is explained by an increase in the proportion of medical and biological emergencies.

Separately, it should be emphasized on cases of increased risk of emergence of man-made origin in the zone of anti-terrorist operation (ATO) due to the destruction of many industrial and residential buildings as a result of hostilities. Damage to critical

infrastructure objects, including water treatment plants, chemical plants and agricultural enterprises, caused by an armed conflict in eastern Ukraine, poses a serious threat to the population and the environment not only in Donetsk and Lugansk regions, but also throughout Ukraine. Therefore, the protection of infrastructure in the territory of a military conflict is extremely important. The OSCE has repeatedly urged the conflicting parties in the Donbass to make every effort to protect the vital objects of the civilian infrastructure of the region, since damage to any of them could lead to an ecological catastrophe, which would significantly aggravate the situation on both sides of the collision [17].

According to the OSCE Special Monitoring Mission, which operates in the area of the anti-terrorist operation, Donetsk filtration station during the year 2017 at least 9 times suffered significant damage. This led to her stoppage [18]. In general, due to the shelling of militants, this station, which provides 600,000 people with water on both sides of the line of demarcation, did not work for 45 days. According to the OSCE, more than 1 million people may be left without water because of numerous damages to infrastructure as a result of hostilities in the Donbass.

It is worth noting the growth of cybernetic threats for critical infrastructure of the state caused by hacker attacks, which can lead to failures of important information infrastructure. So, on June 27, 2017, Ukrainian institutions became victims of a large-scale cyberattack carried out with the help of the virus Petya. A. Hacker attacks were aimed at objects of critical information infrastructure of energy generating and power supply companies, transport facilities, a number of banking institutions, telecommunication companies. The reports of defeats of the information systems of commercial companies came from the Auchan network, the DHL postal service, commercial banks and telecom operators [19]. The virus struck numerous state resources, in particular the system of the Ministry of Infrastructure, the State Fiscal Service of Ukraine, the electricity distribution networks of Ukrenergo, etc.

Given the scale of cross-border impact of emergencies of various origins, international cooperation in disaster risk reduction is extremely relevant to Ukraine. The importance and the need to coordinate efforts to reduce the risk of emergency at the international, regional and local levels in recent years was paid in several multilateral framework programs and declarations. Among these important "Yokohama Strategy and Plan of Action for a safer world: Guidelines for disaster management, preparedness and mitigation", which was adopted in 1994 and today is the basic document of the United Nations in the field of disaster risk reduction and mitigating their negative consequences [21].

In general, this approach involves performing at the state level the relevant tasks, the most important of which is the inclusion of disaster risk reduction measures in the plans and programs of socio-economic development [23]. The ultimate goal is to prevent the emergence of new ones and to reduce the known disaster risks by implementing complex and inclusive economic, structural, legal, social, health, cultural, cultural, educational, environmental, technological, political and institutional measures that prevent and reduce the propensity to influence dangerous factors and vulnerability to disasters, increase readiness for response and recovery, and thus strengthen the potential of counteraction to the state.

## 4 RISK ASSESSMENT FOR CRITICAL INFRASTRUCTURE

In general, risk assessment includes several steps:

- identification of risks as a process of their recognition and description,
- risk analysis, which involves understanding the nature of the risk and determining its level,
- risk assessment, which involves comparing the results of the risk analysis with the criteria for determining whether the risk is acceptable.

If the problem of preventing and preparedness for a particular type of threat is addressed, the risk can be quantified as a function of the likelihood of occurrence of a threat, exposure (the total cost of all elements exposed to risk) and vulnerability [24].

At the same time, in the EU countries, in order to carry out a National Risk Assessment for critical infrastructure, it is recommended to use a risk matrix with a dimension of 5 x 5 as a means of visualizing the evaluation results (Figure 1).

Risk assessment should be based on three different categories of exposure and consider the negative consequences for human (population), economy (and environment), as well as political and social consequences. At the same time, for the first two categories of influence, the negative consequences are determined quantitatively as the number of dead (injured) persons or economic losses in UAH (Euro). Consequences for the third category of influence, considering social and political interconnections, are determined by qualitative indicators.

In the European Union, each country has to carry out risk assessments for each category of consequences and, accordingly, build three different risk matrices when conducting risk assessments for critical infrastructure. Among the various threats of different origins for critical infrastructure security (CI), the following are the most important [24]:

- natural: floods, extreme weather events, forest fires, earthquakes, epidemics and pandemics, epizootics,

• man-made:
  a) inadvertent: industrial accidents, nuclear / radiological accidents, transport accidents, loss of critical infrastructure,
  b) malicious: cyberattacks, terrorist attacks.

Particular attention is needed to the interconnections and interdependence between threats of natural origin when the emergence of some dangerous phenomena leads to the formation of new through the mechanism of cascading effects (Table 2).

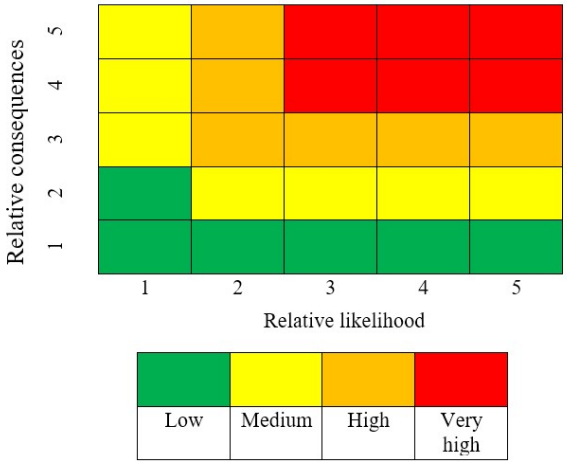



**Fig. 1** Sample of the risk matrix
Source: [24].

**Table 2** Interconnections and interdependencies between threats

| Threat | Related Threats |
|---|---|
| Hazardous weather phenomena | Floods, landslides, forest fires, pollution, loss of critical infrastructure, traffic accidents |
| Earthquakes | Landslides, tsunami |
| Landslides, volcanoes | Transport accidents |
| Nuclear, chemical and transport accidents, loss of critical infrastructure | Pollution, terrorist and cybernetic attacks |
| Loss of critical infrastructure | Floods, pollution, loss of critical infrastructure, pandemics |
| Pollution | Pandemic |

Source: [24].

The awareness of cascading effects of modern threats is quite complicated due to the interconnection of infrastructure objects and the environment surrounding it. Failure to reach agreement of stakeholders and political leadership in predicting and mitigating the negative effects of new threats, primarily of natural origin, can lead to serious violations of the critical infrastructure in the near future.

The risk assessment of the death from the ES of natural and man-made origin is carried out in accordance with available data from the State Service of Emergency Situations of Ukraine regarding the threats of different origin, therefore a risk matrix is constructed. At the same time, according to statistical data, the likelihood of emergence of dangerous situations and the likelihood of death from them is calculated, and on this basis a corresponding dependence is formed that was done to address the purpose of this publication (Figure 2). The likelihood of the ES was determined as the ratio of the number of ES of the corresponding type to the total number of ES that occurred during the year.

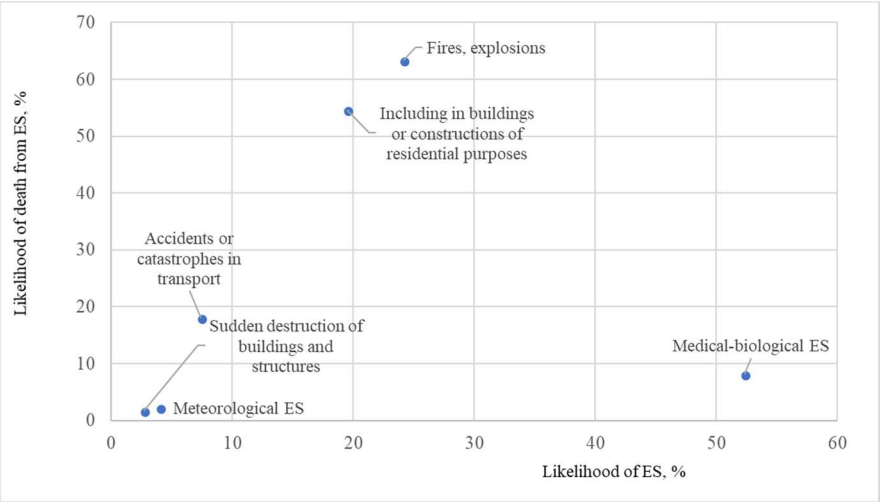
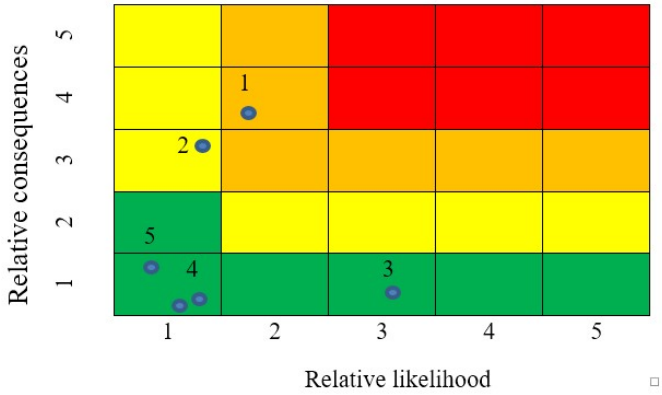



**Fig. 2** Dependence between likelihoods of and the death from ES in 2016
Source: author's calculations.

The results of the assessment indicate that the greatest likelihood of occurrence of emergency situations with human victims in Ukraine is typical for medical-biological emergency, fires, explosions in buildings and structures, accidents and transport accidents. At the same time, the greatest likelihood of death is characterized by dangerous situations arising as a result of fires, explosions, including in buildings and structures, as well as accidents and catastrophes in transport.

Considering the obtained results of estimating the likelihood of occurrence of ES and death from them, the risk matrix is then constructed according to the model used in the EU (Figure 3).




*Notes:*
1 – ES as a result of fires, explosions;
2 – ES due to fires, explosions in buildings or constructions of residential purposes;
3 – medical and biological emergency;
4 – meteorological ES;
5 – ES due to accidents or disasters in transport

**Fig. 3** Risk matrix of death from the ES in 2016
Source: author's calculations.

Analyzing the results obtained, we can note: an increased risk of death is characteristic of emergency situations, which occurred during fires, explosions. The average level of risk is due to fires, explosions in buildings or buildings of residential purposes. Other types of ES, which are considered in this study, including medical-biological, meteorological, emergency situations, which occurred as a result of the sudden destruction of buildings and structures, are characterized by low risk of death.

From the point of view of making managerial decisions on reducing the victims from the ES of different origin, it is obvious that the primary attention should be directed specifically to counteracting and reducing the risks of the occurrence of fires and explosions, including at objects of critical infrastructure. In turn, management and, to a certain extent, risk reduction involves a process of risk mitigation under different scenarios, such as:

- avoiding risk, the completion or rejection of the activity causing the risk,
- taking risk in order to take advantage of certain opportunities,
- exclusion of a source of risk,
- change of likelihood,
- change of consequences,
- distribution of risk to the other party by contracting or financing risks,
- preservation of existing risk level based on a coherent solution.

In the conditions of complex interconnections and mutual influences of the main factors of the formation of the ES, an effective process of reducing the risk will involve the combined implementation of several of these scenarios, which can be worked out based on the use of expert assessment methods.

At the same time, it should be borne in mind that the risk matrix (Figure 2) in determining the economic losses and losses for the environment from the ES will be significantly different from that discussed above (Figure 3), since for Ukraine the greatest economic losses are characterized by threats of natural origin, in first of all those that are related to meteorological emergency and dangerous exogenous geological processes.

## 5 CONCLUSIONS

Nowadays in Ukraine there are tendencies for further decrease of the level of safety and reduction of the duration of work of objects of critical infrastructure that arise as a result of overtime operation of buildings, structures, equipment and engineering networks operating on the brink of exhaustion of their resource and forming the serious threats of emergencies of natural and anthropogenic character for the safety of the operation of critical infrastructure objects.

In the conditions of the hybrid war in the east of Ukraine there is an increase in the risks of the emergence of man-made industrial origin in the ATO zone due to the destruction of many industrial and residential buildings as a result of hostilities. The damage caused by the military conflict in eastern Ukraine to critical infrastructure objects, in particular water treatment plants, chemical plants and agricultural enterprises, poses a serious threat to the population and the environment of the region.

A significant risk of emergencies of natural and man-made origin on the territory of the ATO generates the presence of a large number of flooded and semi-flooded mines in the Luhansk and Donetsk regions, which have a permanent hydraulic connection with the existing mines. The unsatisfactory ecological condition in coal mining areas of the Donbas is intensified due to the concentration of enterprises in the metallurgical and chemical industries, which increases the technogenic load on the environment and creates real threats to the formation of an emerging man-made state with massive negative consequences for the population.

The development and implementation of measures to reduce the risks of ES of different origins on critical infrastructure objects is hampered by the lack of a national body responsible for coordinating existing state security and crisis response systems in the area of critical infrastructure protection. To date, the state has no single methodology for assessing threats and risks to critical infrastructure, which also complicates the development of measures to prevent and minimize the negative consequences of the ES, which are possible on the territory of Ukraine, on critical infrastructure objects.

## 6 SUGGESTIONS

At the moment one of the most significant step forward is the development and submission to the Parliament of Ukraine of a draft law "On the Protection of Critical Infrastructure", which should address all aspects of the establishment of a state system for the protection of critical infrastructure, including the body responsible for coordinating critical infrastructure protection activities.

Among them priority should be given to defining the functions and powers of central executive authorities in the area of critical infrastructure protection, rights, responsibilities and responsibilities of owners and operators of critical infrastructure objects, the introduction of criteria for assigning objects to critical infrastructure on a critical scale, the order of their certification and categorization.

At the same time priority should be given to the formation of criteria for assigning objects, including potentially dangerous, to critical infrastructure, assessing threats to critical infrastructure, developing plans to ensure the sustainability of the functioning of critical infrastructure and the formation of a nationwide system of interaction in accordance with the competence of ministries.

Prospects for further exploration in this area are related to conducting a risks assessment of natural and man-made disasters for critical infrastructure objects of Ukraine, their categorization by types and levels of risk, and also the development of well-grounded measures to prevent the emergencies with large negative consequences for the CI.

Such risk assessment will require the availability of operational and objective data on monitoring of actual natural and man-made threats, especially regarding economic losses from their implementation. In this regard, the restoration of the proper functioning of the Government Information and Analytical System for emergencies and the improvement of the system of early detection of threats and reduction of the risks of emergencies of natural and man-made origin for CI are important.

This system will be able to provide an effective interagency information interaction and support for the adoption of management decisions to prevent the emergence of different origins based on the use of modern methods of spatial analysis and mathematical modeling of emergencies based on a comprehensive processing of operational, analytical, reference, expert and statistical data from different information sources.

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