SCIREA Journal of Information Science and Systems Science
ISSN: 2995-3936
http://www.scirea.org/journal/ISSS
September 11, 2025
Volume 9, Issue 3, June 2025
https://doi.org/10.54647/isss120415

Methodology for Assessing War Risks to Educational Institutions in Ukraine

Vasilij Begun[1], Valerii Kolesnykov[2,*], Vladyslav Mykhailiuk[3]

[1]Institute of Mathematical Machines and Systems Problems of the National Academy of Sciences of Ukraine, 42 Academician Glushkov Avenue, Kyiv 03187, Ukraine

[2]Faculty of Computer Science and Cybernetics, Taras Shevchenko National University of Kyiv, 4d Academician Glushkov Avenue, Kyiv 03680, Ukraine

[3]Kyiv, Ukraine

*Corresponding author: valerii.kolesnykov@knu.ua

Abstract

This article aims to develop a methodology for assessing risks to educational institutions related to Russia’s military aggression against Ukraine and to carry out a comparative analysis of this methodology with the one approved by the Cabinet of Ministers of Ukraine.

Research methodology. The methodology we propose for assessing risks relies on probability theory and mathematical statistics. We utilized expert assessments approved by the Ministry of Social Policy of Ukraine to rank the risks.

Research results. We propose a methodology based on the probability distribution of enemy attacks across Ukraine's territory, constructed using the von Mises-Fisher distribution on a sphere in three-dimensional space. We use Bayes' estimates to evaluate the degree of risk. The general statistics of enemy attacks determine the distribution parameters. A computational experiment was conducted based on the statistics of attacks during the summer of 2025. The results obtained indicate that the level of absolutely unacceptable risk is exceeded even for educational institutions with the most favorable factors characterizing the damage to the territory.

Practical significance. The proposed methodology has a better justification than the approved methodology; therefore, its application and further approval may be advisable for the efficiency and correctness of the ranking of educational institutions by risk level. The experiments carried out and their refinements may also serve as an argument in favor of the fact that, under the given circumstances, ranking of institutions is not advisable at all, which can save time and resources of the authorities of Ukraine by redistributing budgets, giving priority to eliminating the root causes of high risks for institutions.

Keywords: *risk analysis, safety, probability, Russo-Ukrainian war.*

1. Introduction

Resolution [1] of the Cabinet of Ministers of Ukraine dated August 2, 2024, No. 866 "On Approval of the Methodology for Assessing Security Risks in the Education System Associated with the Armed Aggression of the Russian Federation against Ukraine" contains a description of the methodology for ranking educational institutions according to the level of risk. Experts in the field of risk assessment have repeatedly criticized this methodology. Among the arguments expressed in personal and official letters to the Ministry of Education and Science of Ukraine were both comments on the incorrect use of terms in the document ("security risk", "risk of the presence of <…> infrastructure facilities"). As we can see, there is a terminological error even in the title of the document, which does not align with the research in the field of security by foreign and domestic scientists [2-11] and the international standard [12]. Also, the choice of formula (1) for calculating the result, the coefficients of its components, etc., is absolutely not justified. Unfortunately, the Ministry of Education and Science ignored this criticism. Still, the resolution mentioned above also obliges the Ministry of Education and Science, together with the Ministry of Development of Communities and Territories, the Ministry of Defense, and the Office of the National Security and Defense Council of Ukraine, to submit proposals to the Cabinet of Ministers of Ukraine annually to improve the methodology. We hope that the Ministry of Education and Science will continue to consider the comments and refine the methodology. We also urge the Ministry to address the current lack of need to rank educational institutions by risk level. This work is of great practical importance due to the Ukrainian government's intention to allocate substantial funds, as indicated by the results of calculations [13-16]. To substantiate our position, we will propose alternative formulas for risk assessment, comparing them with the formulas from the approved methodology, and also analyze the results of computational experiments obtained by our method.

2. Methodology Description

2.1. Approved Methodology

In the approved methodology, several quantities shape the overall risk level for a specific educational institution. The first one is the distance in kilometers from the institution to the borders with the Russian Federation and the Republic of Belarus, as well as the distance to the line of combat operations. The second one is the number of infrastructure facilities that may be targets of shelling at a distance of less than 1 km from the institution. The third one is the number of hits in the territory with a radius of 1 km around the institution (hereinafter referred to as the "adjacent territory") by missiles, unmanned aerial vehicles, or other means of delivery. And, this is an indicator of the presence of territories from which artillery shelling can be carried out at maximum distances from the educational institution by various types of artillery. Additionally, we highlight educational institutions located in temporarily uncontrolled territories separately. These factors, in themselves, form an adequate list of sources of danger that we consider in a risk assessment. However, the indicator related to artillery shelling could be combined with the indicator of distance to the borders and to the line of combat operations, since the approved methodology primarily lists the territories from which forces can potentially conduct artillery shelling, and, in addition to the temporarily occupied territories and the territories of the Russian Federation and the Republic of Belarus, it additionally indicates only the territory of the Republic of Moldova within the Transnistrian region. But in general, this set of indicators does not raise any questions. What raises questions and dissatisfaction are the formulas and procedures used to combine these indicators and obtain the final result. The first indicator of distance is independent of the others so that we will omit it. The other three indicators are combined into one using the following linear formula

$$R = 0.25 \times R^{\text{infra}} + 0.25 \times R^{\text{strike}} + 0.5 \times R^{\text{artillery}}. \tag{1}$$

When the assessor takes the parameters of a linear combination literally, the number of infrastructure objects nearby and the number of hits in the adjacent territory, which are natural numbers, do not adequately reflect the risk values. Additionally, it is unclear from what considerations the coefficients of the formula were derived. Why the indicators are combined linearly, and not according to another principle, is also not explained anywhere. Moreover, this formula alone is insufficient to determine the risk category of an educational institution. The approved methodology requires the creation of a database for all educational institutions, with their individual results calculated according to equation (1). The next step in this methodology should be dividing the entire sample into terciles using the 3-quantile method. In addition to considering the individual characteristics of the institution and the separately calculated result, the methodology determines the final rank of the institution by comparing it with the ranks of all other institutions. This strategy of additional comparison raises specific questions, both regarding why the authors of the methodology chose the tercile and 3-quantile method in general, and not other methods of dividing the sample, and regarding its necessity in general.

2.2. Proposed Methodology

2.2.1. Distance Factor

First, let's combine the distance indicator with the borders and the line of combat operations, as well as the indicator related to artillery shelling. The approved methodology identifies the territories from which artillery shelling is possible. In addition to the temporarily occupied territories and the territories of the Russian Federation and the Republic of Belarus, it also indicates the territory of the Republic of Moldova within the Transnistrian region. This combination is rational. Let's determine the risk indicator p_{dist} by comparing the distance L from the educational institution to the borders with the Russian Federation and the Republic of Belarus and to the lines of combat operations with some critical distances L_1 and L_2, which we determine according to the analysis of the range of enemy artillery and the analysis of the enemy army's advances.

$$p_{dist} = \begin{cases} p_{unacceptable}, & if\ L \le L_1, \\ p_{high}, & if\ L_1 < L \le L_2, \\ p_{acceptable}, & if\ L > L_2. \end{cases} \tag{2}$$

The values of $p_{unacceptable}$, p_{high} and $p_{acceptable}$ are also determined by experts and can be chosen, for example, as indicated in the Order of the Ministry of Labor and Social Policy of Ukraine dated 04.12.2002 No. 637 “On Approval of the Methodology for Determining Risks and Their Acceptable Levels for Declaring the Safety of High-Hazard Facilities” [2] for territorial risk.

2.2.2. Hit Factor

Let us now consider the indicator of the number of hits in the adjacent area. Based on this indicator, we should estimate the probability of hitting this area during the next attack. To assess the likelihood of an enemy object hitting a particular section of the territory of Ukraine, we need to determine the density f of the distribution of enemy objects hitting (hereinafter referred to as the density) on the entire controlled territory of Ukraine $UA_{free} \subseteq S^3$, where S^3 is a sphere in three-dimensional space. This density will obviously be heterogeneous, since the same critical infrastructure objects are more important targets for enemy objects than a random house in a random place on the territory of Ukraine. Thus, we will assume that the locations of the local density maxima correspond to those of the critical infrastructure objects.

First, let us assume that there is only one infrastructure object of the chosen type I (for example, a specific CHP power station) located on the territory of Ukraine at the coordinate $\mu \in S^3$. Then, the enemy objects will have this single infrastructure object as their target, so we can assume that the density in the neighborhood of the point μ will be much higher. Since the enemy object may not hit the infrastructure object exactly for one reason or another, we can assume that in this case, the density is the density of the von Mises-Fisher distribution [17] for a sphere in three-dimensional space with the mean direction of μ and the concentration parameter k.

$$f(\omega) = g_{MF}(\omega, \mu, k) = \frac{k}{4\pi \sinh k} e^{k(\mu,\omega)}, \ \omega \in S^3. \tag{3}$$

The value of the concentration parameter k can be found using statistics on those enemy objects that targeted a specific critical infrastructure object and, as a result, hit at the appropriate distance from the object (the reason for this can be both the successful shooting down of the enemy object and its insufficient accuracy, which is unprincipled in this case). For this, the following formulas can be used [18]:

$$r=\bar{x},\bar{x}=\frac{1}{2M}\sum_{i=1}^{M}x_i+\frac{1}{2M}\sum_{i=1}^{M}\hat{x}_i, \tag{4}$$

$$k=\frac{r(3-r)}{1-r^2}. \tag{5}$$

Here $x_i \in S^3, i=\overline{1,M}$ are the coordinates of the hits of those enemy objects intended to destroy this infrastructure object. $\hat{x}_i \in S^3$ is a set of coordinates that is symmetric to x_i relative to the coordinates of the infrastructure object μ . Adding these coordinates to the consideration is necessary for the correct calculation of the parameter k , since the original formulas from [18] estimate the parameters μ and k simultaneously, but in this case, we know μ . This addition of symmetric vectors does not affect the value of k if the vectors $\sum_{i=1}^{M}x_i$ and μ are collinear, that is, when the original statistics are already symmetric with respect to the vector of mathematical expectation in a certain sense.

When adding critical infrastructure objects of the same type to the territory, the density will look like a sequence of "hills". Of course, these hills may have different heights and widths, as the statistics of damage may vary for other critical infrastructure facilities. However, since the territory of Ukraine is quite large and there are many infrastructure objects on it, it may happen that for a particular infrastructure facility, there is no data on its damage or attempts to damage it. At the same time, similar data for other infrastructure facilities of the same type could exist. To determine the density component corresponding to a given infrastructure object, we propose to combine the statistics of shelling for all facilities of the same type with the subsequent determination of a single coefficient of damage concentration for all these facilities. We carried out the combination of statistics and the determination of the coefficient using formulas (4)-(5) and shifting all coordinates to a single pole.

However, there is still a part of enemy shot-down objects or those that fell far from the infrastructure, or about which it is impossible to determine where they headed and what their target was. Therefore, for this category of enemy objects, a uniform density $\frac{1}{S_{UA_{free}}}$ can be introduced throughout the territory of Ukraine, where $S_{UA_{free}}$ is the area of the free territory of Ukraine. The formula for the density of the damage distribution then takes the following form.

$$f(\omega) = p_{target}\left(\sum_I \frac{p_I}{n_I}\sum_{i=1}^{n_I} g_{MF}(\omega, \mu_i, k_I)\right) + \frac{1 - p_{target}}{S_{UA_{free}}},\ \omega \in S^3. \tag{6}$$

Here $I \in \{I_1, I_2, \ldots, I_J\}$ are the types of critical infrastructure objects, p_{target} is the proportion of attacks from statistics aimed at damaging the infrastructure (targeted attacks), n_I is the number of infrastructure objects of type I, p_I is the proportion of attacks from the total number of targeted attacks aimed at damaging infrastructure objects of type I, k_I is the concentration coefficient of targeted attacks on infrastructure objects of type I. Then the probability of damaging the territory with a radius of 1 km around the educational institution can be calculated as follows:

$$p(x) = \int_{D_x} f(\omega)\, d\omega. \tag{7}$$

Here $x \in S^3$, $D_x \subseteq S^3$ is a point in Ukraine and the adjacent territory, respectively, and the integral is a surface integral of the first kind.

The density function constructed in this way can be classified as secret information, since, as noted, the hills in it correspond to the coordinates of critical infrastructure objects or military facilities. Therefore, we could not consider the data on this distribution as freely distributed. But at the same time, each educational institution must calculate its risk value using this distribution. To solve this problem, we propose applying a Bayesian estimate. That is, we will determine the risk value $p_{strike}(i)$ as the most likely value of the probability of shelling the adjacent territory from among all possible positions of the educational institution on the controlled territory of Ukraine, assuming the number of previous i neighboring territory attacks and the total number of successful attacks N. This value will be the same for all institutions with the same value , regardless of their geographical location. That is, this risk value does not take into account the distance to the borders or to the line of combat operations.

Since in this case we do not take into account the coordinates of the educational institution at all, we will assume that it can be located anywhere in the free territory of Ukraine with equal probability. We can estimate Bayes' likelihood as follows.

$$
\begin{aligned}
& p_{strike}(i) = \int\limits_{UA_{free}} p(x) P\{x \mid i\, hits\, of\, N\, total\} dx = \\
& = \int\limits_{UA_{free}} p(x) \frac{P\{i\, hits\, of\, N\, total\, in\, D_x\}}{\int_{UA_{free}} P\{i\, hits\, of\, N\, total\, in\, D_x\} dx} dx = \\
& = \frac{\int_{UA_{free}} p(x) P\{i\, hits\, of\, N\, total\, in\, D_x\} dx}{\int_{UA_{free}} P\{i\, hits\, of\, N\, total\, in\, D_x\} dx} = \\
& = \frac{\int_{UA_{free}} p(x) \binom{N}{i} (p(x))^i (1-p(x))^{N-i} dx}{\int_{UA_{free}} \binom{N}{i} (p(x))^i (1-p(x))^{N-i} dx} = \\
& = \frac{\int_{UA_{free}} \left(\int_{D_x} f(\omega) d\omega\right)^{i+1} \left(1-\int_{D_x} f(\omega) d\omega\right)^{N-i} dx}{\int_{UA_{free}} \left(\int_{D_x} f(\omega) d\omega\right)^{i} \left(1-\int_{D_x} f(\omega) d\omega\right)^{N-i} dx}.
\end{aligned} \tag{8}
$$

By approximating the integrals in the numerator and denominator with arbitrary precision $\varepsilon > 0$ and the following sequence of conclusions

$$
\begin{aligned}
& \frac{\Sigma(y_j)^{i+1}(1-y_j)^{N-i}}{\Sigma(y_j)^{i}(1-y_j)^{N-i}} \le \frac{\Sigma(y_j)^{i+2}(1-y_j)^{N-i-1}}{\Sigma(y_j)^{i+1}(1-y_j)^{N-i-1}} \Leftarrow \\
& \Leftarrow \Sigma(y_j)^{i+1}(1-y_j)^{N-i} \Sigma(y_k)^{i+1}(1-y_k)^{N-i-1} \le \\
& \le \Sigma(y_j)^{i+2}(1-y_j)^{N-i-1} \Sigma(y_k)^{i}(1-y_k)^{N-i} \Leftarrow \\
& (y_j)^{i+1}(1-y_j)^{N-i}(y_k)^{i+1}(1-y_k)^{N-i-1} + \\
& +(y_k)^{i+1}(1-y_k)^{N-i}(y_j)^{i+1}(1-y_j)^{N-i-1} \le \\
& \le (y_j)^{i+2}(1-y_j)^{N-i-1}(y_k)^{i}(1-y_k)^{N-i} + \\
& +(y_k)^{i+2}(1-y_k)^{N-i-1}(y_j)^{i}(1-y_j)^{N-i} \Leftarrow \\
& \Leftarrow y_j(1-y_j)y_k + y_k(1-y_k)y_j \le y_j^2(1-y_k) + y_k^2(1-y_j) \Leftarrow \\
& \Leftarrow 2y_j y_k \le y_j^2 + y_k^2.
\end{aligned} \tag{9}
$$

one can prove an intuitively obvious result regarding the effect of the number of hits on the Bayes estimates for the next attack.

$$i \le j \Rightarrow p_{strike}(i) \le p_{strike}(j). \tag{10}$$

Thus, we can start calculating $p_{strike}(i)$, starting from $i = 0$, until at some i_0 the result exceeds the level of completely unacceptable risk. In this case, there is no need for further calculations for $i > i_0$, since by formula (10), all subsequent estimates will also be above the level of completely unacceptable risk.

2.2.3. Infrastructure Factor

Now, let's move on to the indicator of nearby infrastructure. The user must enter the number of critical infrastructure facilities of each type located within 1 km of the institution. We suggest using the following formulas to determine the corresponding risk.

$$p_{infra} = M \int_{D_x} f_1(\omega, y_1, y_2, \ldots, y_K) d\omega, \tag{11}$$

$$f_1(y_1, y_2, \ldots, y_K) = p_{target}\left(\sum_{i=1}^{K} C_i g_{MF}(\omega, y_i, k_i)\right) + \frac{1 - p_{target}}{S_{UA_{free}}}, \tag{12}$$

$$y_i \sim U(D_x) \ \forall i = \overline{1, K}. \tag{13}$$

That is, to determine the level of risk associated with the presence of infrastructure facilities nearby, we find the average value of the probability of the subsequent damage to the territory adjacent to the institution, assuming that the infrastructure facilities can be located anywhere in a circle with a radius of 1 km around the institution and are distributed independently of each other. Thus, firstly, we do not refer to the density function f, and therefore, we preserve the confidentiality of the data. Secondly, we can correctly process the situation when the user enters incorrect data, that is, a combination of quantities of infrastructure facilities that is impossible from the point of view of the mutual location of the local maxima of the function f. In the above formulas, the generated density f_1 consists of those density terms that correspond to the types and quantities of critical infrastructure facilities entered by the user. The coefficients C_i and k_i are equal to the corresponding parameters of these terms.

2.2.4. Main Formula

Then the formula for determining the result can be written as follows:

$$p = \max\left(p_{dist}, p_{strike}, p_{infra}\right). \tag{14}$$

This formula, unlike the approved one, operates on probabilities and is based on statistics of previous hits. In addition, each component of the formula separately affects the classification result of the educational institution. To classify an institution as having an acceptable level of risk, all three values must have values within the range that corresponds to no more than an acceptable level of risk. If at least one of these values exceeds the level of absolutely unacceptable risk, then the institution itself should be classified as having an unacceptable level of risk.

3. Computational Experiment

Let's carry out a computational experiment, the statistics for which will be based on data for June and July 2025 regarding shelling. References [19-20] contain a list of news articles about enemy attacks during this period. According to open sources, during this period of time, the aggressor launched more than 400 missile attacks and almost 12,000 launches of long-range drones, nearly 85% of which were intercepted or destroyed by the Armed Forces of Ukraine. Some of the enemy targets remain unneutralized; almost 20% of the remaining unneutralized enemy targets have struck infrastructure facilities. Since open sources do not mention the destruction of secret military facilities, and we can't determine the percentage of enemy facilities that cause damage to the infrastructure, not just hit the infrastructure, 3,000 successful enemy attacks were simulated for the computational experiment. We assume that attackers aimed half of the modeled attacks at one of the 120 infrastructure facilities, for which we also randomly generated the coordinates. The total number of attacks more or less corresponds to the number of successful attacks for the summer of 2025 (in fact, this value itself is not as significant as the percentage distribution of attacks). The specially increased percentage of targeted attacks allows us to estimate the risk for an individual institution from below, since the greater the proportion of attacks aimed at destroying infrastructure facilities, the smaller the proportion for intimidation and accidental damage to the territory.

The Bayes estimates for zero hits and one hit in this case are as follows:

$$p_{strike}(0) \approx 2\times10^{-7}, \tag{15}$$

$$p_{strike}(1) \approx 2,5\times10^{-6}. \tag{16}$$

4. Discussion

Let us consider the value (15). In itself, it corresponds to the range of absolutely acceptable risk ([2]). This value indicates the probability of hitting only one subsequent enemy object without neutralizing it. In June-July 2025, there were already almost 1,900 such objects, and their number is only growing, with no reason to expect a decrease in the future. In [2], the authors defined the degree of risk as the probability of an accident occurring in the following year. In our case, an accident is the hit of an enemy object in the adjacent territory. Suppose there can be even close to 10,000 "successful" enemy attacks throughout the territory of Ukraine in a year. In that case, we can estimate the probability that at least one of these objects will hit the adjacent territory using the Taylor series expansion:

$$p_{strike} = 1-\left(1-p_{strike}(0)\right)^{10^4} \approx p_{strike}(0)\times10^{4} \approx 10^{-3}. \tag{17}$$

This degree of risk already greatly exceeds the limit of absolutely unacceptable risk, which, according to the Order 637, is equal to 10^{-5}. And all these considerations apply to educational institutions near which there have been no attacks so far. We have not yet taken into consideration the parameters of distance to the borders and the presence of known infrastructure nearby, which can only increase this estimate. And, as we indicated earlier, this is still a lower estimate of the result; that is, in fact, the risk level may be even higher. For one attack, the result is an order of magnitude higher, and according to (10), any other number of attacks will also determine the Bayesian estimate to be within an absolutely unacceptable risk range. This result indicates that, given the current level of threat and the frequency of massive attacks, it is unacceptably dangerous everywhere. Therefore, ranking educational institutions when they are all at an unacceptable level of risk may be inappropriate and untimely.

Of course, this proposed method of calculating the risk does not yet take into account some other statistical properties of the sample of hits, such as, for example, the fact that the central, northern, and eastern regions of Ukraine suffer the most from intimidation attacks, which may necessitate its own correction for the risk assessment in the western areas. It was also not taken into account that a significant number of attacks occur in the agglomeration of regional centers. Additionally, for a more accurate result, it is necessary to use real, not generated, statistics. However, on the other hand, when calculating the Bayes estimate, we do not take into account that the location of educational institutions is usually near areas with a high concentration of people, and therefore near various infrastructure facilities. In our calculations, we assumed a random location of educational institutions in Ukraine; thus, taking this aspect into account, the estimate, on the contrary, will only increase. Of course, we need to carry out new experiments to obtain an accurate result. Still, even now, we can say that the result will most likely not decrease by even two orders of magnitude to cross the line of completely unacceptable risk. We urge the Ministry of Education and Science of Ukraine to consider our advice on improving the methodology and, based on the results of computational experiments, determine the feasibility of this approach.

5. Conclusions

The article proposes a new methodology for assessing the risk to educational institutions posed by the Russian Federation's military aggression against Ukraine. We propose to enhance the current methodology approved by the Cabinet of Ministers of Ukraine by providing improvements and mathematical justification for the formulas. We carried out a comparative analysis of the current and proposed methodologies. Based on open data on shelling of the territory of Ukraine during the summer of 2025, a computational experiment was conducted according to the proposed methodology. The results obtained indicate that there is no need to rank educational institutions by risk level, as even under the most favorable input data, the level of risk of damage exceeds the threshold of an absolutely unacceptable risk by two orders of magnitude.

References

[1] Resolution of the Cabinet of Ministers of Ukraine dated August 2, 2024 No. 866 “On Approval of the Methodology for Assessing Security Risks in the Education System Associated with the Armed Aggression of the Russian Federation against Ukraine”. URL: https://zakon.rada.gov.ua/laws/show/866-2024-п#Text. (in Ukrainian).

[2] Order of the Ministry of Labor and Social Policy of Ukraine dated 04.12.2002 No. 637 “On Approval of the Methodology for Determining Risks and Their Acceptable Levels for Declaring the Safety of High-Hazard Facilities”. URL: https://zakon.rada.gov.ua/rada/show/v0637203-02#Text. (in Ukrainian).

[3] Rasmussen N.C., Reactor *Safety Study. An Assessment of Accident Risks in U.S. Commercial Nuclear Power Plants. WASH-1400 (NUREG 75/014),* Nuclear Regulatory Commission, Washington: U.S. , 1975, 198 p.

[4] Vesely W.E., "Minimal cut set failure and repair," *Reliability Engineering*, Vol. 5, Issue 2, P. 65–72, 1983.

[5] Guidelines for Analysis of Data Related to Ageing of Nuclear Power Plant Components, *JRC Scientific and Technical Report,*. Luxemburg: European Communities, 2009, 202 p.

[6] Tan S., Weinert D., Joseph P., Moinuddin K., "Sensitivity and Uncertainty Analyses of Human and Organizational Risks in Fire Safety Systems for High-Rise Residential Buildings with Probabilistic T-H-O-Risk Methodology," *Applied Sciences*, 11(6):2590, 2021, https://doi.org/10.3390/app11062590

[7] Tan S., Moinuddin K., "Systematic review of human and organizational risks for probabilistic risk analysis in high-rise buildings," *Reliability Engineering & System Safety*, 188, 2019, doi:10.1016/j.ress.2019.03.012.

[8] Sun X., Luo M., "Fire Risk Assessment for Super High-rise Buildings," Procedia Engineering, 71, 492-501, 2014, doi:10.1016/j.proeng.2014.04.071.

[9] Begun V.V. (2020). Methodological basis of information technology of safetymanagement based on risk-oriented approach, Doctor's of Technical Sciences thesis, Institute of Mathematical Machines and Systems Problems of the National AcademyofSciences of Ukraine, Kyiv, Ukraine. 562 p. URL: http://www.immsp.kiev.ua/postgraduate/Dysertaciji/dis_Begun_2020.pdf. (in Ukrainian).

[10] IEC 31010:2019. (2019). Risk Management – Risk Assessment Techniques. International Standard. Edition 2. ISBN 978-2-8322-6989-3. Geneva: ISO/IEC. 264 p.

[11] Begun V.V. (2016). Implementation of information technologies in the SafetyField. *Scientific and Technical Information.* No. 1. P. 39-45. URL: http://nbuv.gov.ua/UJRN/NTI_2016_1_9. (in Ukrainian).

[12] Fussell J.B., Vesely W.E., "A New Methodology for Obtaining Cut Sets for Fault Trees," *Transactions of the American Nuclear Society,* Vol. 15, N 1, P. 262–263, 1972.

[13] Internet source: "Oksen Lisovyi: To take one child offline, today we pay an average of UAH 100–150,000. But it is justified," URL: https://lb.ua/society/2024/08/22/630591_oksen_lisoviy_shchob_vivesti.html, (in Ukrainian).

[14] Order of the Ministry of Education and Science of Ukraine from August 7, 2024. № 1112 "On the approval of the Procedure and conditions for obtaining general secondary education in communal institutions of general secondary education under martial law in Ukraine (registered with the Ministry of Justice of Ukraine on August 8, 2024 under № 1222/42567)," URL: https://mon.gov.ua/npa/pro-zatverdzhennia-poriadku-ta-umov-zdobuttia-zahalnoi-serednoi-osvity-v-komunalnykh-zakladakh-zahalnoi-serednoi-osvity-v-umovakh-voiennoho-stanu-v-ukraini-zareiestrovanyi-u-ministerstvi-iust, (in Ukrainian).

[15] Internet source: Albul S., "Shmyhal: today the government distributes another 5 billion hryvnias of additional subsidies for shelters in schools," URL: https://lb.ua/society/2024/08/20/630413_shmigal_sogodni_uryad_rozpodilyaie_shche.html, (in Ukrainian).

[16] Internet source: Albul S., "The government plans to return 300,000 schoolchildren to safe offline education by the end of the year," URL: https://lb.ua/society/2024/08/13/629257_uryad_planuie_kintsya_roku_povernuti.html, (in Ukrainian).

[17] Fisher R. A., "Dispersion on a sphere," *Proc. R. Soc. Lond. A.*, 217 (1130): 295–305, 1953, doi:10.1098/rspa.1953.0064
[18] Sra S., *"*A short note on parameter approximation for von Mises-Fisher distributions: And a fast implementation of I_s(x),*"* *Computational Statistics*, vol. 27, p. 177–190, 2011.
[19] Internet source: "List of missile strikes during the Russian invasion (summer 2025)," URL: https://uk.wikipedia.org/wiki/Перелік_ракетних_ударів_під_час_російського_вторгнення_(літо_2025) (in Ukrainian).
[20] Internet source: "List of Shahed 136 BPLA attacks in 2025," URL: https://uk.wikipedia.org/wiki/Перелік_атак_БпЛА_Shahed_136_у_2025_році (in Ukrainian).