ORIGINAL PAPER

DOI: 10.26794/2304-022X-2025-15-4-172-188
UDC 614.842.8(045)
JEL M54

Managing Organizational Risks in Russia's Oil and Gas Enterprises Based on Expert Assessment

E.V. Gvozdev
Moscow State University of Civil Engineering, Moscow, Russian Federation

ABSTRACT

The Comprehensive Security System (CSS) is designed to prevent the emergence and development of risks — technical, organizational-technical, and purely organizational — at enterprises within Russia's oil and gas sector. This study focuses on reducing losses by assessing and managing organizational risks that arise from insufficient actions or shortcomings on the part of personnel responsible for ensuring the effective operation of the CSS. The aim of the research is to identify an approach that makes it possible to convert qualitative indicators of organizational risks into quantitative terms (a measurable negative impact). In the course of the study, the author substantiates the use of an expert-based method (priority ranking) to evaluate risks associated with inadequate actions by management bodies that oversee subordinate personnel. This method has advantages and introduces elements of novelty compared with current solutions used in practice. When applied together with the functionality of the Gaussian probability distribution, it allows experts to determine specific safety areas in which organizational risks arise due to insufficient control measures. In real organizational systems, having reliable information with weighted values for all identified risks makes it possible to construct a ranked list, determine priorities, and develop a set of preventive measures. The article provides an example illustrating how personnel in various safety areas influence the overall state of the CSS, and it justifies the feasibility of applying the *priority-ranking method* in practice to obtain quantitative results for organizational risks.

Keywords: integrated security system; organizational risks; prioritization method; Gauss probability distribution; expert decision; insufficient actions

For citation: **Gvozdev E.V. Managing organizational risks in Russia's oil and gas enterprises based on expert assessment. *Upravlencheskie nauki = Management Sciences*. 2025;15(4):172-188. DOI: 10.26794/2304-022X-2025-15-4-172-188**

INTRODUCTION

Knowledge concerning the implementation of a risk-oriented approach aimed at reducing damage from hazardous events at enterprises of the Russian oil and gas sector is continuously expanding through new analytical findings on technical, engineering-organizational, and organizational risks [1]. For the overall component across all risk groups, the presence of a substantial share (approximately 75%) associated with the human factor has been confirmed [2].

Approaches to the study of the first two types of risks are comprehensively presented in the works of the A.A. Blagonravov Institute of Machine Science of the Russian Academy of Sciences (risk analysis and safety of hazardous production facilities) [3]; the Scientific and Technical Center for Industrial Safety Research (safety justification of hazardous production facilities, as well as risk analysis, safety substantiation, and safety declaration provided as commercial services upon request from legal entities) [4–6]; the All-Russian Research Institute for Fire Protection of EMERCOM of Russia (organizational and methodological support for activities related to independent fire risk assessment carried out on a fee-for-service basis upon request from legal entities) [7–9]; and the All-Russian Research Institute for Civil Defense and Emergency Situations of EMERCOM of Russia (improvement of emergency risk management methods in response to national security challenges and threats in the development of regulatory legal acts and normative documents) [10; 11].

As regards the assessment of organizational risks, further research is required to enhance technosphere safety at protected facilities of oil and gas enterprises in Russia [1]. The author identifies a problem situation consisting in the need to manage organizational risks manifested as hazardous events (accidents and fires), proposes an expert-based method for their assessment, and substantiates its advantages.

RESEARCH METHOLOGY

The activities of oil and gas enterprises in Russia aimed at preventing the emergence and manifestation of organizational risks are schematically presented *in Fig. 1.*

The developed sequence of actions makes it possible to account for the dynamics of damage reduction U_{OC} resulting from the manifestation of organizational risk R_O in hazardous events (accidents and fires), once the indicators of negative impact become known in quantitative terms (measure):

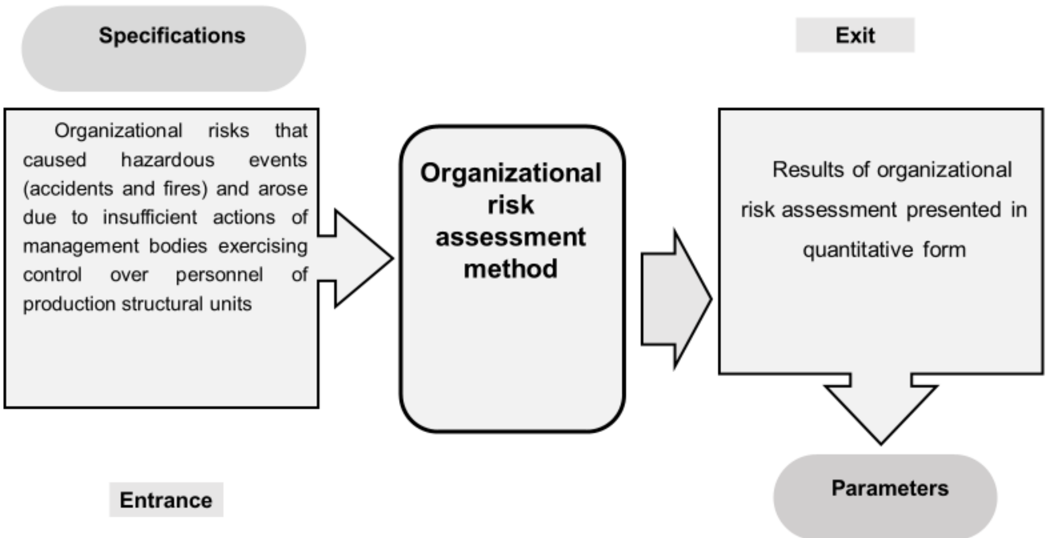


Fig. 1. **The Sequence of Transformation of Organizational Risks from Characteristics to Parameters**

Source: Compiled by the author.

$$U_{oc} = F_{U_{oc}}\{R_0, P\} = \sum_i \left[F_{U_i}(R_{0_i}, P_i\right] = = \int C(R_0)P(R_0)\,dR_0 = \int C(P)R_0(P)\,dP, \quad (1)$$

where

P — probability of occurrence of hazardous events (accidents and fires);

i— groups of adverse factors influencing the outcome in the form of hazardous events (accidents and fires);

C— weighting functions accounting for the interdependence of risks.

Since the objective of the study was to substantiate the selection of an expert method capable of transforming qualitative characteristics of organizational risks into quantitative ones, the parameter (M) — representing the weight of the negative impact of organizational risk — should be employed within the range M_{min}= 0,001; BM_{max}= 0,999. Then

$$R_O = \int_{M\,min}^{M\,max} f(M)\cdot P(M)\,dM, \quad (2)$$

where $f(M)$ denotes the distribution density of organizational risk groups, taking into account the frequency of their manifestation in hazardous events; $P(M)$ — denotes the probability of manifestation of organizational risks in hazardous events, determined using the functional framework of Bayesian belief networks [2, 12, 13].

The shortcomings of existing risk assessment methodologies are presented in *Table 1*.

At present, various methods are used for risk assessment, for example FMEA1 (Failure Mode and Effects Analysis) [1] and Bayesian analysis (or Bayesian networks2) [2]. The advantage of the former lies in identifying potential failures of production equipment and their impact on the functioning of facilities or processes, the environment, and personnel. This makes it possible to increase equipment reliability, reduce negative environmental impact, lower operating costs, and ultimately enhance the company's business reputation. The FMEA method has gained wide recognition and is applied primarily in the assessment of *technical risks*. Bayesian analysis and Bayesian networks may be useful in developing a probabilistic Poisson model for events such as accidents, enabling the identification of causal relationships among variables (represented as a Bayesian network). However, in practice they are used infrequently due to the complexity of representing all interactions within a technical system, as conditional probabilities become excessively extensive. The above methods have the following limitations:

- obtaining results requires the input of empirical data expressed in quantitative form;
- meaningful results are obtained only in domains where probabilistic laws play a decisive role.

A distinguishing feature of selecting an expert-based method for assessing organizational risks is the identification of the deviation magnitude of the baseline vector from the chosen direction, that is, the capacity of the governing body to adjust the trajectory toward achieving the objective. As noted earlier, a key problem is that initial risk data are presented as qualitative descriptions rather than formalized information. This circumstance confirms the feasibility of transforming them into quantitative form.

Activities of industrial enterprises aimed at reducing the risks of damage caused by hazardous events should be carried out not only in the domain of managing technical and engineering-organizational risks. The field of assessment and management of organizational risks also requires particular attention [14], since this group of risks:

- arises in the process of managerial influence exerted by the governing body on personnel of production structural units;

[1] GOST R 27.303–2021 (IEC 60812:2018).Dependability in engineering. Failure Mode and Effects Analysis (FMEA) URL: https://meganorm.ru/Data/758/75897.pdf

[2] GOST R IEC 31010–2021. Dependability in engineering. Risk assessment techniques. URL: https://docs.cntd.ru/document/1200180987

Table 1

Disadvantages of Existing Risk Assessment Methods

Rostechnadzor Order No. 387 dated 03.11.2022	Order of the Ministry of Emergency Situations of Russia dated 26.06.2024 No. 533	Order of the Ministry of Labor of Russia dated December 28, 2021 No. 926	Disadvantages
Qualitative Description of Risks			
Risk prioritization: 1, 2, 3 (based on accident hazard categorization)	–	+	The nature of interrelations is not taken into account when one safety domain affects another and when they interact. No risk result is presented in the form of a weighted quantitative value; therefore, it is impossible to determine risk priority when forming a unified ranked list.
Risk grading: A, B, C, D (from lowest to highest).		+	
Risk significance: high, medium, low.		+	
Quantitative Representation of Risks			
Numerical expression of pipeline depressurization risk: 10^{-n}/year, where *n* is the exponent value.	Quantities characterizing risks in determining calculated evacuation time (minutes)	–	Sensitivity to measurement errors (significant uncertainty). Alternative relationships with the influence of external factors are not considered.
Probabilistic relation to risk realization (1–100%), with representation of probability values 10^{-n}/year, where *n* denotes the risk magnitude exponent.		–	

Источник / Source: составлено автором / Compiled by the author.

- is identified and prevented through continuous monitoring conducted by industrial and fire safety departments and occupational safety units. These subdivisions oversee compliance with regulatory legal acts and normative documents approved in the areas of industrial safety (Rostekhnadzor), emergency protection (EMERCOM of Russia), and occupational safety (Ministry of Labor). The reports produced do not contain information on deficiencies within a specific safety domain in which such risk arose and manifested itself in the form of a hazardous event. All changes occurring in organizational management systems can be represented as a trajectory of the development (emergence, manifestation, realization) of organizational risk processes R_O in the state space of the system, with zonal boundary delineation (*Fig. 2*).

Let us consider *Fig. 2*:

1. In the zone highlighted in green (lower part), all production processes in the technical system are carried out without disruptions — this corresponds to state S_0.

2. The area marked in yellow (middle part) relates to the zone where organizational risks R_{NDD} and R_{ND}, emerge; under favorable conditions they may manifest as hazardous events (accidents or fires) — this corresponds to state S_n ;

3. The section highlighted in red (upper part), where organizational risks R_{NDD} and R_{ND} have become causes of hazardous events (accidents or fires), represents the zone in which various damage-development scenarios unfold; this corresponds to state S_i. If, within the *organizational* system in which the initiating event (IE) occurs (i.e., organizational risks R_{NDD} and R_{ND} arise),

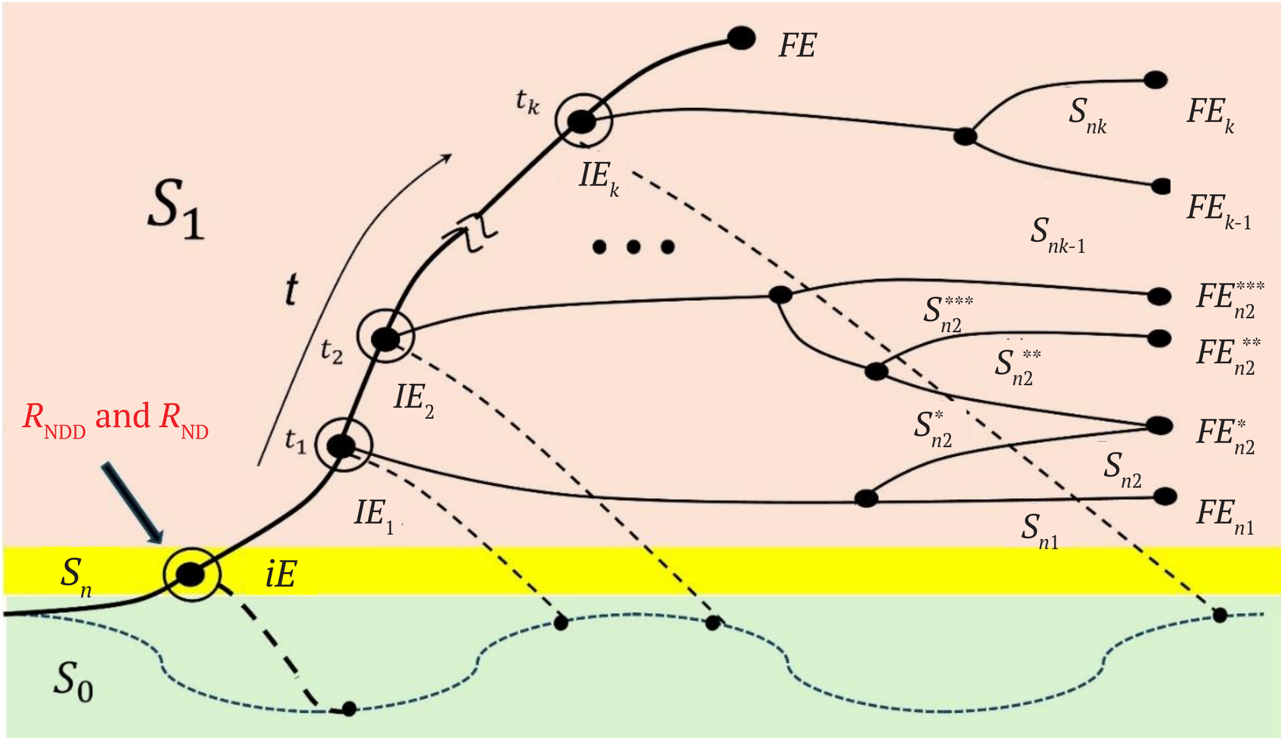


Fig. 2. **Trajectory with the Process of the Emergence and Manifestation of Organizational Risks in Dangerous Events**

Source: Compiled by the author.

conditions are created that lead to deviation toward the zone associated with state S_1, then numerous damage scenarios S_{ij}. may be realized in the *technical* system. The final state (*FS*) for each scenario differs (see *Fig. 2*):

$$FS_{ij} \neq FS^{*}_{ij} \neq FS^{**}_{ij} \neq FS^{***}_{ij}. \quad (3)$$

If, during an incident (failure), the *technical* system is capable of returning from S_1 to S_0 within the shortest time interval, then in approximately 20% of accidents fires occur that cause maximum damage and disable elements of the technical system for an extended period. In this context, there is an opportunity to prevent the emergence of organizational risks in the zone corresponding to state $S_{П}$, and when they transition into the zone associated with state S_1 (points (t_1, t_2, t_k), to implement a set of protective measures.

Risk will be understood as a consciously recognized danger (threat) of the occurrence of a negative event in any system, with consequences[3] determined in time and space [1]. A consciously recognized danger (threat) may appropriately be defined as the conditions under which risk manifests (or escalates), ultimately transitioning into a final phase involving damage caused by hazardous factors (accidents or fires). Given the specifics of assessing organizational risks, it is recommended to consider them as:

- insufficient actions of personnel responsible for safety assurance and exercising control over the staff of production structural units — R_{NDD};
- deficiencies in personnel performance when complying with regulatory legal acts and normative documents — R_{ND}.

The overall indicator of organizational risks R_0 for a selected period may be calculated using the following expression:

[3] Glossary of Terms and Definitions of EMERCOM of Russia. URL: https://mchs.gov.ru/ministerstvo/o-ministerstve/terminy-mchs-rossii/term/3579.(date of access: 13.07.2025).

$$R_0(t)=\frac{\sum_{i=1}^{j}(R_{\text{NDD}})+\sum_{i=1}^{j}(R_{\text{ND}})}{n\cdot(R_{\text{NDD}})+n\cdot(R_{\text{ND}})}(t), \quad (4)$$

where $n{\cdot}(R_{\text{NDD}})$ and $n{\cdot}(R_{\text{ND}})$ denote the number of accident reports included in the sample (units); t —the period under consideration (month, quarter, year).

To identify organizational risks, it is advisable to employ both individual and group expert assessment methods.

Furthermore, explanatory guidance should be provided to experts regarding the following components:

- evaluation of the priority of qualitative risk characteristics and the type of scale applied;
- sequence of procedures or operations aimed at forming judgments;
- order of actions intended to solve the task of processing expert The author proposes the use of an ***expert-calculation method***, specifically the *priority-ranking method* [15], which belongs to a new class of approaches and enables the transformation of qualitative expert assessment results into quantitative form (i.e., determining the magnitude of negative impact).

Application of this method makes it possible to:

- enable a group of experts to select the functional domain (industrial safety; fire safety; occupational safety; production structural units) in which an organizational risk emerged due to insufficient control-related actions and manifested itself as a hazardous event. In this case, experts are able to determine the degree of personnel involvement in its occurrence: direct (*absolute attribution*), mediated (*priority attribution*), or indirect (*relative attribution*);
- obtain for each organizational risk an individual numerical value M (weight of negative impact of organizational risk) within the range диапазоне $M_{\min}$= 0,001; $M_{\max}$= 0,999.

THEORETICAL BASIS FOR THE STUDY

Expert methods applied in practice are generally reduced to solving problems through priority ranking based on the collective judgment of experts [16]. Such a decision is formed by comparing the current state space of the system with the existing risks $M_R(t)$ and by developing a set of organizational and technical measures — $M_M(t)$ aimed at preventing them, expressed as

$$M_R(t)=\begin{pmatrix} n_{11}, & n_{12}, \cdots & , n_{1,k_1} \\ n_{21}, & n_{22}, \cdots & , n_{1,k_1} \\ & \cdots & \\ n_{75,1}, & n_{75,2}, \cdots & , n_{75,k_{75}} \end{pmatrix}, \quad (5)$$

$$M_M(t)=\begin{pmatrix} n'_{11}, & n'_{12}, \cdots & , n'_{1,k_1} \\ n_{21}, & n_{22}, \cdots & , n'_{1,k_2} \\ & \cdots & \\ n'_{75,1}, & n'_{75,2}, \cdots & , n'_{75,k_{75}} \end{pmatrix}$$

where n_{ij} and n'_{ij} are parameters of the compared values of elements included in the respective arrays, taking into account the discrete deterministic functional relationship between them. Accordingly, on the coordinate plane, the interaction of such data arrays $M_R(t)$ and $M_M(t)$ may be represented as an area bounded by vec-

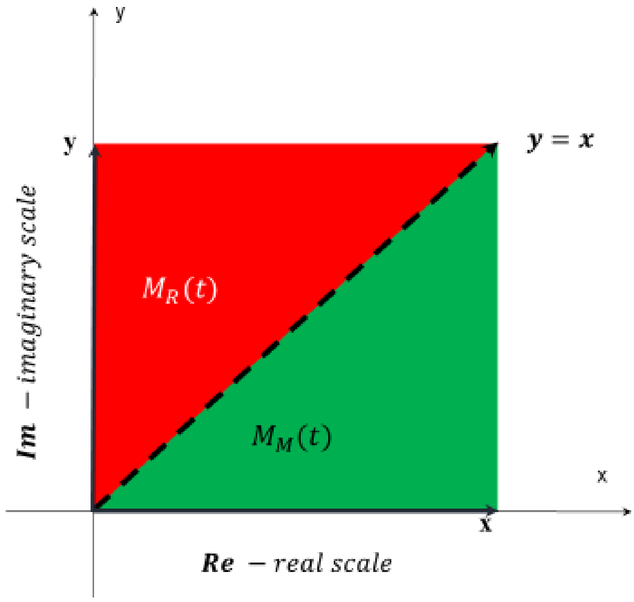


Fig. 3. **The Basic Directional Vector *y*=*x*, Separating the Areas of the Data Arrays $M_R(t)$ and $M_M(t)$**

Source: Compiled by the author.

tors (y) and (x) of the corresponding dimensionality. As abstract objects, two right isosceles triangles colored red and green are proposed for consideration *(Fig. 3)*.

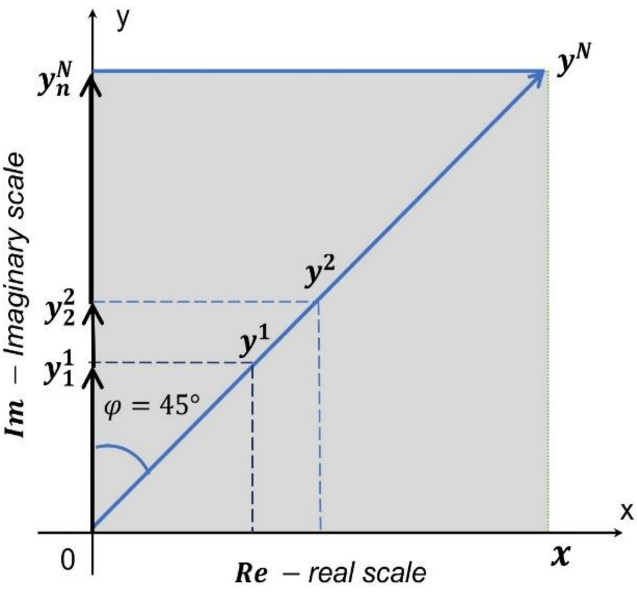


Fig. 4. **The Vector *x*, as a Square Value Plotted on a Real Scale**

Source: Compiled by the author.

In accordance with the concept of integrated safety, the compared arrays (see *Fig. 3*) are balanced by the *baseline directional vector* ($y = x$); in this case, some elements from the array $M_R(t)$ are transformed to determine the elements n_{ij} of the array$M_M(t)$. Such a condition makes it possible to focus on identifying new organizational risks R_0 and, consequently, to obtain the outcome of the influence of the implemented measures expressed by the relation ($y < x$). This enables the decision-maker to represent changes in the impact indicators of the array $M_M(t)$ on $M_M(t)$ based on variation in the orthogonal orientation of the resultant vector. The importance of applying a balancing *baseline directional vector* lies in the fact that the magnitude (x,y) may be interpreted as the square of the length of a vector plotted on the *Re* scale of real numbers (the x-axis) (*Fig. 4*).

If the causes of organizational risks are considered as the area of a square representing the entire set of risks under study, it becomes possible to identify a region (designated by a directional vector) represented by the area of a rectangle corresponding to new (previously unexamined) organizational risks. Over time, it

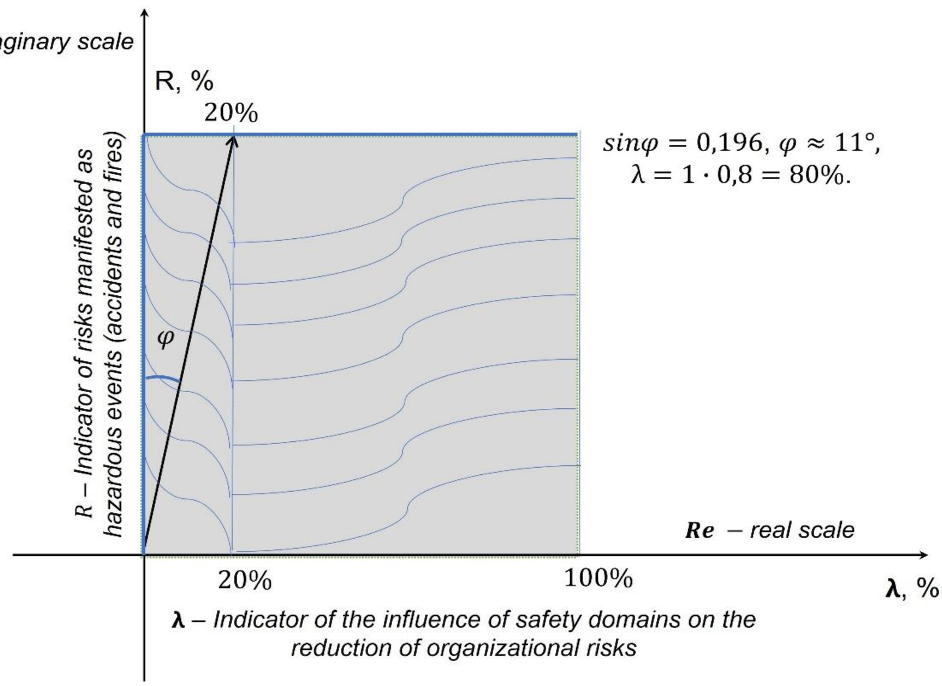


Fig. 5. **The Allocated Share with the Risks Manifested in Dangerous Events (Accidents and Fires)**

Source: Compiled by the author.

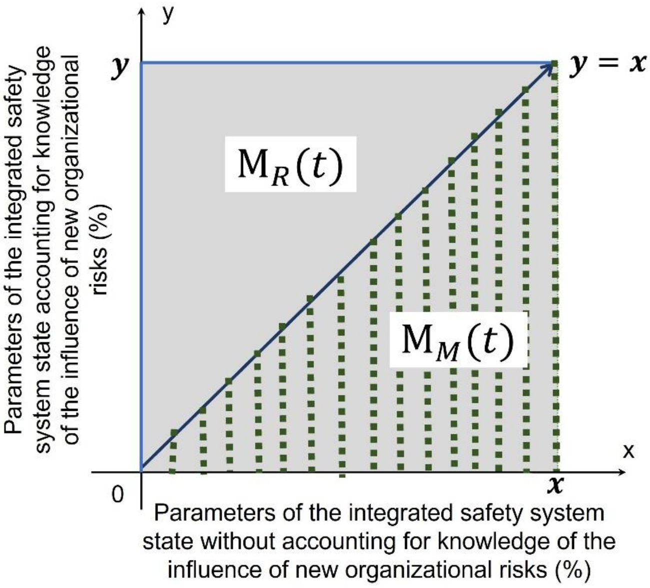


Fig. 6. **A Dedicated Area for Displaying New Organizational Risks Manifested in Dangerous Events (Accidents and Fires)**

Source: Compiled by the author.

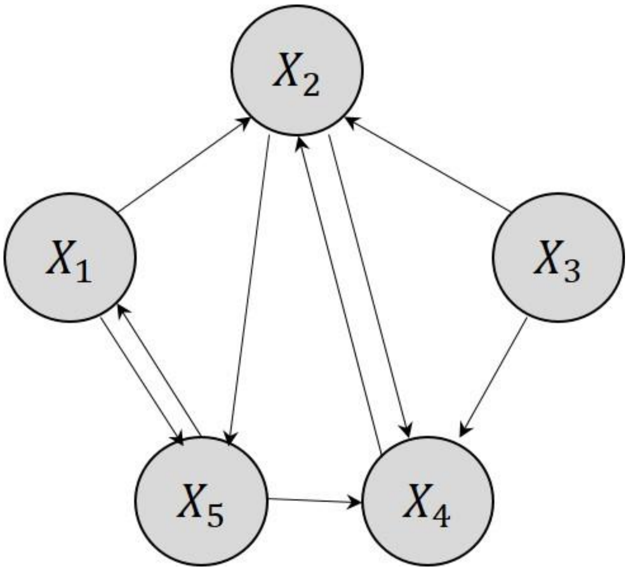


Fig. 7. **Graph of the *n*-object evaluation result**

Source: Compiled by the author.

becomes necessary to reduce this area through the development and implementation of a specific set of actions addressing such unexplored risks as R_{NDD} and R_{ND} (*Fig. 5*).

Since the article addresses the quality of the influence exerted by personnel of higher professional education units at enterprises in preventing organizational risks R_0, the dynamics of effectiveness of the measures included in the array $M_M(t)$ will be positive when the area of the isosceles triangle belonging to the array $M_R(t)$, changes, and negative under analogous changes in the triangle belonging to the array — $M_M(t)$ (*Fig. 6*).

When applying the proposed approach in practice, it becomes possible:

- on the one hand, to use the *baseline directional vector* as the reference scale on which emerging risks exert no influence, i.e., the influence indicator $\lambda_{inf} = 0$;
- on the other hand, the impact of efforts aimed at preventing the emergence of organizational risks makes it possible to bring the system state at oil and gas enterprises in Russia to a normalized condition, that is

$$\lambda_{inf}\{IS; FS; OS; PSU\} \Rightarrow 1.$$

JUSTIFICATION FOR THE PREFERENTIAL SELECTION OF THE PRIORITY-RANKING METHOD FOR ASSESSING ORGANIZATIONAL RISKS

Each of the n–objects ($X_1, X_2, \ldots, X_n$) (*Fig. 7*) corresponds to a vertex of a graph reflecting the result of comparison between two evaluated objects. The task is to determine the maximum of functions of several variables that are related to one another through rank dependence.

Если рассматривать любую расчетную модель с точки зрения ее упрощения, то (согласно условиям предпочтительности) целесообразно применять квадратичную форму

$$A = \begin{vmatrix} a_{11} & a_{12}\cdots & a_{1j}\cdots & a_{1N} \\ a_{21} & a_{23}\cdots & a_{2j}\cdots & a_{2N} \\ \cdots & \cdots\cdots & \cdots\cdots & \cdots \\ a_{i1} & a_{i2}\cdots & a_{ij}\cdots & a_{iN} \\ \cdots & \cdots\cdots & \cdots\cdots & \cdots \\ a_{n1} & a_{n2}\cdots & a_{nj}\cdots & a_{nN} \end{vmatrix},$$

If any computational model is considered from the standpoint of simplification, then (according to preference conditions) it is appropriate to apply a quadratic form, where a_{ij}— risk indicators obtained through pairwise comparisons;

N— matrix rank;

$a_{n1}, a_{n2}, ..., a_{nj}, a_{nN}$— risk indicators included in the j-th row of matrix A;

$a_{1N}, a_{2N}, ..., a_{jN}, a_{nN}$ — j-risk indicators located in the j-th column of matrix (A).

In this case,

$$a_{ij} = \begin{cases} 1, if\ X_i > X_j \\ 0,5, if\ X_i = X_j \\ 0, if\ X_i < X_j \end{cases},$$

where $i = j \to \{1, 2, \ldots, n\}; a_{ij} = 0,5.$

$X_i > X_j$ indicates the priority of one evaluated object relative to another, while $X_i = X_j$ indicates equal importance of the evaluated objects.

The use of a qualitative ratio scale makes it possible:

- on the one hand, to determine organizational risks R_0 as a result of identified deviations (insufficient actions of functional domains [industrial safety; fire safety; occupational safety; personnel of production structural units] when implementing control measures with respect to staff), represented by the coefficient of negative impact K_{NI} (associated with domain X_i;
- on the other hand, to establish the nature of damage caused by each hazardous event (accident or fire).

The justification presented above largely corresponds to the *priority-ranking method* (PRM) [15]. This method has certain advantages over other expert assessment techniques, as it enables:

- identification of interrelations among elements comprising the system state space;
- representation, where possible, of quantitative assessments (subjective, expert-based) [16];
- formulation and transformation of the problem into a logically structured form;
- expansion of analytical capabilities through the application of mathematical modeling tools and optimal decision selection [17], as well as other methods used in practice, including statistical distributions (*Tables 2* and *3*).

In scientific studies [18, 19], when sampling data constrained by dependent indicators of qualitative characteristics (3–4 units), it is considered preferable to use an average indicator reflecting the typical level of a feature formed under the influence of dominant non-random factors. In this context, the normal distribution is appropriate. The use of mean values makes it possible to characterize a specific attribute of a population by a single number, despite variations in its values across individual units. Taking into account the presence of uncertainty when calculating estimates of the studied parameters using a verbal scale, a compromise approach was adopted to select the most preferable weighting value by employing point estimates derived from the law of normal distribution. This approach accounts for the limited number of organizational risks (3–4 units) identified in the reports "Lessons Learned from Accidents" (subsection addressing organizational causes) at Russian oil and gas enterprises. Within this framework:

- on the one hand, point estimates should be applied cautiously when selecting the preferred decision, given the uncertainty in estimating factors and their weights;
- on the other hand, it becomes possible to employ a *ratio scale* constructed on the basis of the functional application of established probabilistic laws. For example, the Gaussian distribution, characterized by the manifestation of specific values of an organizational risk indicator across the *total area* = 100%, and within intervals bounded by $\bar{x} \pm \sigma = 68,2\%$, $\bar{x} \pm 2\sigma = 95,4\%$, $\bar{x} \pm 3\sigma = 99,6\%$. This makes it possible to confirm the reliability of expert judgments when processing questionnaire data at the ***second stage*** of the study (primary processing of survey results), that is, to test them for sensitivity. Since the assessed organizational risks arise and manifest as hazardous events across different safety

Table 2

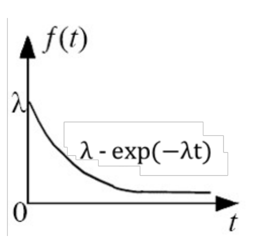
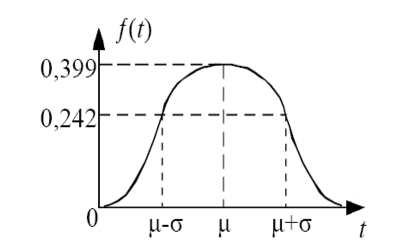
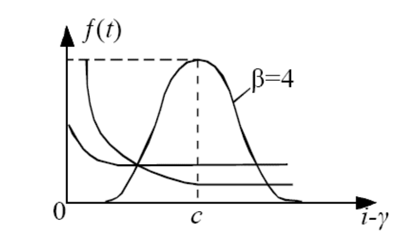
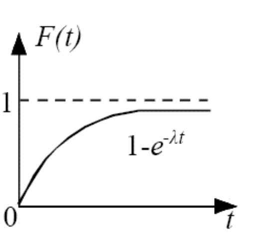
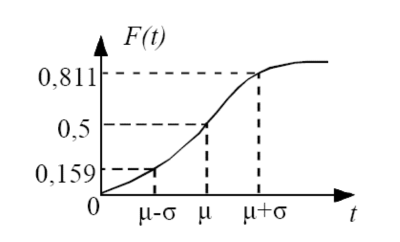
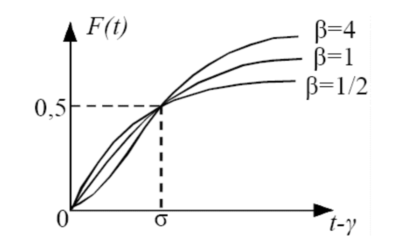
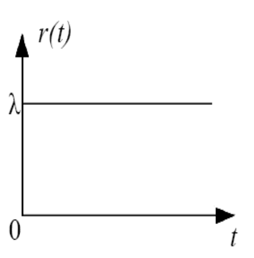
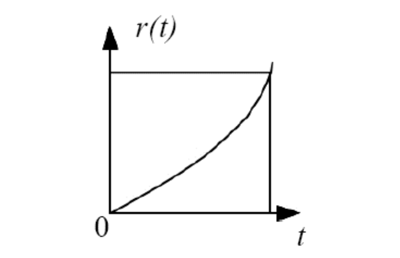
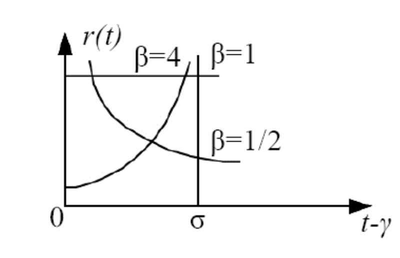
Statistical Distributions Used in Practice (Presented in the Form of Calculation Formulas)

Parameter	Exponential	Normal (Gauss)	Weibull
Probability Density $f(t)$	$\lambda e^{-\lambda t}$	$\frac{1}{\sigma\sqrt{2\pi}} e\left[-\frac{1}{2}\left(\frac{t-\mu}{\sigma}\right)^2\right]$	$\frac{\beta(t-\gamma)^{\beta-1}}{\sigma^{\beta}} e\left[\left(-\frac{t-\gamma}{\sigma}\right)^{\beta}\right]$
Distribution Function $F(t)$	$1-e^{-\lambda t}$	$\frac{1}{\sigma\sqrt{2\pi}}\int_{-\infty}^{t} e^{-\frac{1}{2}\left(\frac{t-\mu}{\sigma}\right)^2} dx, \; (-\infty < t < \infty)$	$1-e\left[-\left(\frac{t-\gamma}{\sigma}\right)^{\beta}\right]$
Magnitude of Variation Limit.	λ	$\frac{f(t)}{1-F(t)}$	$\frac{\beta(t-\gamma)^{\beta-1}}{\sigma^{t}}$

Source: Compiled by the author.

Table 3

Statistical Distributions Used in Practice (Presented in the Form of Graphs

Parameter	Exponential	Normal (Gauss)	Weibull
Probability Density $f(t)$			
Distribution Function $F(t)$			
Magnitude of Variation Limit.			

Source: Compiled by the author.

Table 4

Results with Negative Impact Indicators for Organizational Risks

Security directions, attitude								Sign of the relationship of organizational risk to the direction of safety	Negative impact indicator
								Direct relationship (DR)	0.682
IS		FS		OS		PSU		*Mediated relationship (MR)*	0.272
								Indirect relationship (IR)	0.042

Source: Compiled by the author.

domains (industrial safety, fire safety, occupational safety, and production structural units), they may be treated as independent; therefore, in accordance with formal mathematical reasoning, the author considered it appropriate to assign a specific numerical value to each alternative (*Table 4*).

Such an approach makes it possible to associate specific numerical values with the following qualitative characteristics:

those having a *direct* relationship (*absolute attribution*) to the emergence and escalation of conditions leading to damage from accidents and fires. In proportional terms, the value amounts to approximately 68.2% (≈ 0.682), and this indicator is assigned to one of the domains (industrial safety; fire safety; occupational safety; production structural units);

- those having a *mediated* relationship (*priority attribution*) — approximately 27.2% (≈ 0.272); this indicator is assigned to one of the domains (industrial safety; fire safety; occupational safety; production structural units), even if it had previously been characterized as having a *direct* relationship;
- those having an *indirect* relationship *(relative attribution*) — approximately 4.6% (≈ 0.046); this indicator is assigned to one of the domains (industrial safety; fire safety; occupational safety; production structural units);
- those having *no relationship* (i.e., ≈ 0), corresponding to the domain to which none of the above indicators was assigned[4].

JUSTIFICATION OF THE QUALITY OF EXPERT ASSESSMENT AND VALIDATION OF THE STUDY RESULTS

To summarize the risk assessment with consideration of the influence of personnel from specific safety domains (occupational safety; industrial safety; fire safety) and production structural units on the overall state of the integrated safety system, an expert group was formed comprising specialists from PJSC Mosenergo responsible for analyzing:

- accidents (experts in industrial safety);
- fires (experts in fire safety);
- occupational injuries (experts in occupational safety).

The size of the expert group was calculated using the formula

$$n_{\mathrm{T}} = \frac{c\bar{a}_n - b}{\bar{a}_n\left(1-c\right)}, \qquad (6)$$

[4] Gvozdev E.V., Sadovsky B.S., Gvozdeva E.D. Certificate of State Registration of Computer Software No. 2024680621 (Russian Federation). Calculator for assessing the influence of subsystem personnel on the state of the integrated safety system of explosion- and fire-hazardous enterprises. No. 2024665338, dated 30 Aug 2024.

where n_r — required number of experts; $\overline{a}_n$ — arithmetic mean of the assessments provided by n experts; b — assessment obtained from an additional (n +1)-th expert; c — measure of the influence of a single expert judgment on the group assessment:

$$c = \frac{\overline{a}_{n+1}}{\overline{a}_n}. \tag{7}$$

In this case: c = 1 when $\overline{a}_n = b$; c >1 when $\overline{a}_n < b$; c < 1 when $\overline{a}_n > b$.
Expressing $\overline{a}_{(n+1)}$ through $\overline{a}_n$ and b, the formula takes the form:

$$\overline{a}_{n+1} = \frac{n\overline{a}_n + b}{n+1}. \tag{8}$$

Then the final value is represented as

$$c = \frac{n\overline{a}_n + b}{(n+1)\overline{a}_n}. \tag{9}$$

Each expert was required to solve the task using documentary materials from the commission investigating the accident at PJSC Nizhnekamskneftekhim (Russian oil and gas sector) in 2016. Organizational risks are listed in *Table 5*, and their normalized assessments (obtained by experts through application of the Gaussian probability distribution) are presented in *Table 6*.

The maximum indicator (*Table 6*) corresponds to the assessment of Expert 4 (b = 0.728). The final calculated value is $\overline{a}_n$ =0,47, but $\overline{a}_{n+1}$ =0,51, obtained using formula (8). The measure of influence of an individual expert's judgment on the group assessment was found to be (c = 1.08) in accordance with formula (9). The calculation results confirmed the need to expand the expert group to seven members, as determined by formula (9).

$$n_r = \frac{1,08 \cdot 0,47 - 0,728}{0,47(1 - 1,08)} \approx 7.$$

Thus, the minimum composition of specialists capable of ensuring the required influence of an individual expert's judgment on the group assessment was established [20; 21].

When processing expert data from each analyzed accident report, indicators (coefficients)

Table 5

List of Organizational Risks Formed During the Analysis of Accidents

№	Organizational risks
1	Insufficient tightness of fittings in the installed pipeline section in the lower part of the tank
2	Presence of ignition sources within the tank farm area (failure to shut down the welding station), leading to ignition of a flammable medium.
3	Unsatisfactory organization of acceptance procedures for completed work after equipment installation
4	Violation of procedures for the safe commissioning of the tank after installation
5	Ineffectiveness of production control

Source: Compiled by the author.

Table 6

Results of Expert Risk Assessments in Standardized Form

Experts	1	2	3	4	5
Expert appraisal	0.318	0.318	0.682	0.728	0.318

Source: Compiled by the author.

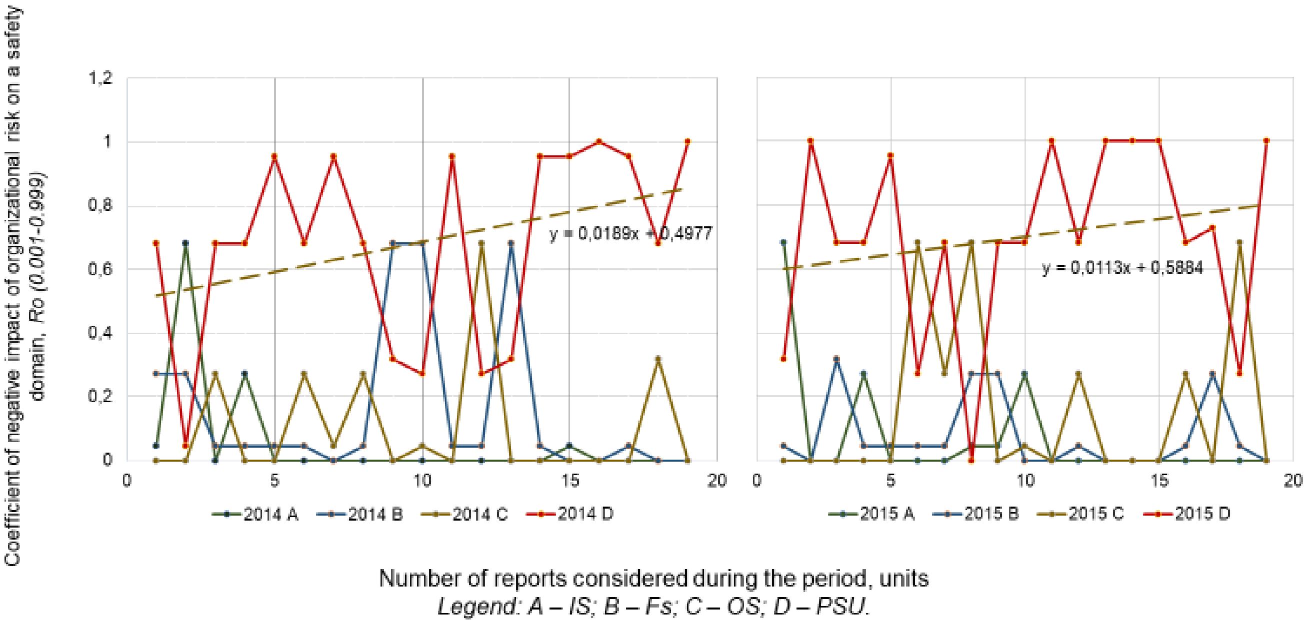


Fig. 8. **Indicators of the negative impact of security trends in 2014–2015**

Source: Compiled by the author.

of the negative impact of organizational risks R_0 are formed for the safety domains (industrial safety; fire safety; occupational safety; production structural units):

$$R_O\{IS;FS;OS;PSU\}\approx$$
$$\approx\lambda_{inf\{1;2;3;4\}}\in\{IS;FS;OS;PSU\},(10)$$

where $\lambda_{inf1}=0{,}682$; $\lambda_{inf2}=0{,}272$; $\lambda_{inf3}=0{,}046$; $\lambda_{inf4}\approx 0$

The results of calculations based on accident reports from oil and gas enterprises in Russia for 2014–2015 are presented in *Fig. 8*.

The value of the efficiency indicators reflecting the influence of each safety domain $\lambda_{inf}S_{\{IS;FS;OS;PSU\}}$ is determined as the difference between the ratios of risk magnitudes: the organizational risk manifested in a hazardous event taken as 100% impact, and the value obtained from expert decisions regarding the domain having a *direct, mediated, or indirect* relationship. Accordingly, the influence efficiency indicators are calculated as

$$\lambda_{inf}S_{(IS)}=1-\varphi_{(S1)};\lambda_{inf}S_{(FS)}=1-\varphi_{(S2)};$$
$$\lambda_{inf}S_{(OS)}=1-\varphi_{(S3)};\lambda_{inf}S_{(PSU)}=1-\varphi_{(S4)},(11)$$

where $\varphi_{\{S1;S2;S3;S4\}}$ are indicators of the negative impact of personnel in each safety domain (industrial safety, fire safety, occupational safety, production structural units) that worsen the overall state of the integrated safety system.

The graphs (*Fig. 8*) allow focus on organizational risks arising within the production structural units domain, which demonstrate a high negative impact indicator - $\varphi_{(S4)}$. The efficiency indicators λ_{inf} calculated using formula (11) for accident reports from 2014–2015 are presented in *Fig. 9*.

To confirm the reliability of expert evaluations, it was necessary to determine the true numerical ratios associated with safety domains according to

$$\overline{w}=\frac{\sum_i^n w_i}{n},\qquad(12)$$

where $\overline{w}$ is the overall weighted-average indicator; n is the number of reports in the sample.

To assess the consistency of expert opinions, the consistency-quality model K_s was applied, defined as the difference between the additive

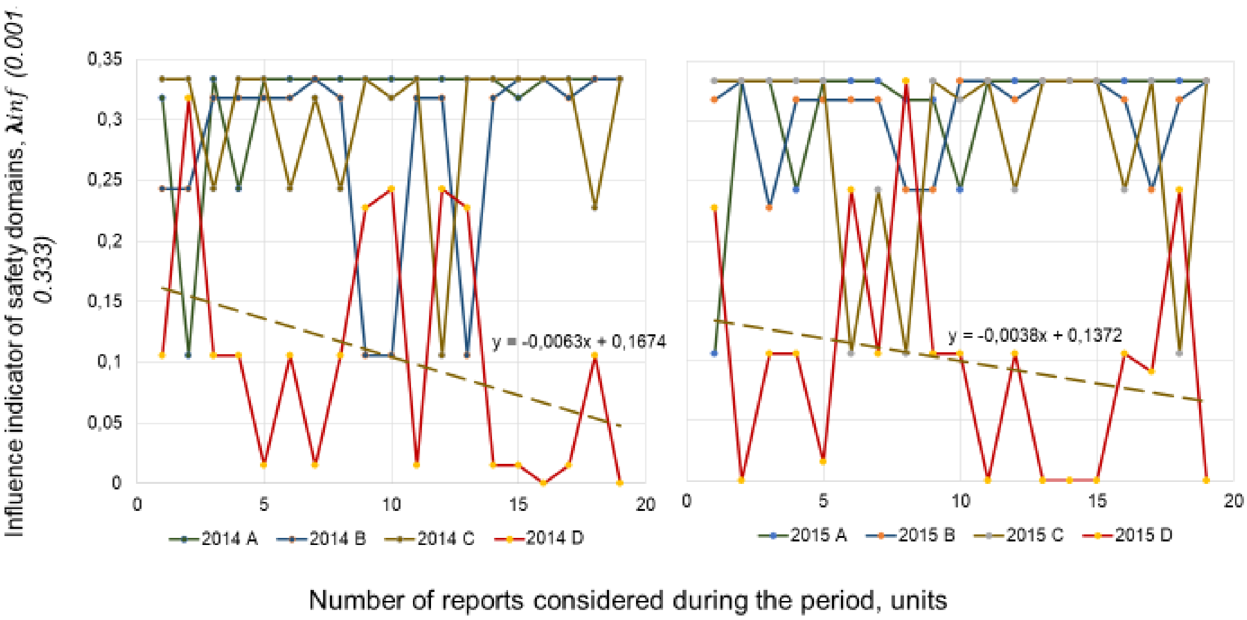


Fig 9. **Indicators of the Effectiveness of the Impact of Security Trends in 2014–2015**

Source: cCompiled by the author.

Table 7

The Results of the Quality Control of the Experts' Consistency

Belongingness factor		Overall results of individual expert assessments with the relationship of the organizational risk indicator to the security area (NO; OO; KO)							E_S	E_I
		1 expert	2 expert	3 expert	4 expert	5 expert	6 expert	7 expert		
IS	DR	0	0	0	0	0	0	0	0.06	0.02
	MR	0.03	0.08	0.08	0.09	0.05	0.06	0.06		
	IR	0.03	0.05	0.09	0.04	0.07	0.05	0.06		
FS	DR	0.09	0.21	0.16	0.12	0.17	0.14	0.11	0.14	0.04
	MR	0.14	0.11	0.09	0.21	0.16	0.12	0.17		
	IR	0.17	0.14	0.11	0.09	0.21	0.16	0.12		
OS	DR	0.08	0.2	0.15	0.11	0.16	0.13	0.1	0.13	0.04
	MR	0.13	0.1	0.08	0.2	0.15	0.11	0.16		
	IR	0.16	0.13	0.1	0.08	0.2	0.15	0.11		
PSU	DR	0.83	0.59	0.69	0.77	0.67	0.73	0.79	0.66	0.06
	MR	0.70	0.71	0.75	0.50	0.64	0.71	0.61		
	IR	0.64	0.68	0.70	0.79	0.52	0.64	0.71		

Источник / Source: составлено автором / Compiled by the author.

weighted average of expert evaluations and the weighted average of their deviations:

$$K_S = E_I, \quad (13)$$

$$E_I = E_S - \sum_{j=1}^{n} w_j, \quad (14)$$

$$E_I = \sum_{i=1}^{n} w_i = 1,0. \quad (15)$$

Here E_S — denotes the result of the weighted averaging of expert evaluations; E_I — denotes the weighted average adjusted for deviations from E_S, w_i and w_j — represent indicators of both evaluations and their deviations.

The data in *Table 7* confirm the quality of agreement among expert assessments, since the final calculated indicator satisfies the condition for solving expert-evaluation problems. $E_I \leq 0,1$.

The validity of the calculations is supported by the correct application of the improved priority-ranking method enhanced by the functionality of the Gaussian probability distribution. Sensitivity is ensured through the use of parametric approaches involving determination of the mean value and its standard deviation expressed as a variance indicator for the sample dataset *(Table 8)*.

CONCLUSION

The study analyzed retrospective, current, and expert information concerning the safe operation of enterprises in the Russian oil and gas sector.

The practical applicability of the improved priority-ranking method for assessing organizational risks arising from insufficient actions of personnel responsible for supervising employees of production structural units has been substantiated.

An example demonstrating the validity of applying this method at oil and gas enterprises in Russia has been presented.

To reduce the risks of damage from hazardous events (accidents and fires) and mitigate their consequences, it is advisable for oil and gas production facilities to develop integrated safety systems — new systems capable of diagnosing problem situations and promptly generating control actions intended for decision-makers and aimed at preventing organizational risks.

Table 8

Mathematical Apparatus That Substantiates the Reliability and Sensitivity of Data Processing

<table>
<tr><th colspan="3">Reliability</th></tr>
<tr><td>Priority –ranking method</td><td>$\frac{1}{\sigma\sqrt{2\pi}} \int_{-\infty}^{t} e^{-\frac{1}{2}\left(\frac{t-\mu}{\sigma}\right)^2} dx \; (-\infty < t < \infty)$</td><td>$\sigma_1 = 0,682$
$\sigma_2 = 0,272$
$\sigma_3 = 0,046$
$\sigma_4 \approx 0$</td></tr>
<tr><th colspan="3">Sensitivity analysis</th></tr>
<tr><td colspan="2">$\overline{x}_a = \frac{\sum_{S=1}^{S=n} x_S m_S}{\sum_{S=1}^{S=n} m_S}$</td><td>$\sigma^2 = \frac{\sum_{S=1}^{S=n} (x_S - \overline{x}_a)^2 \cdot m_S}{\sum_{S=1}^{S=n} m_S}$</td></tr>
</table>

Source: Compiled by the author.

Note: μ – mathematical expectation; (σ_1; σ_2; σ_3; σ_4) – indicators taking into account the standard deviation; $\overline{x}_a$ – the mean value indicator for a data sample; x_S – risk indicator in the middle of the intervals (S) of the interval series; m_S is the indicator of the probability of risk manifestation (frequency, repeatability) of a set of features for an interval series; n – list of risks for the sample object; σ^2 – dispersion measure for a data sample/

REFERENCES

1. Gvozdev E.V. Methodology of risk assessment in the system of integrated safety designed to prevent accidents and fires at explosion and fire hazardous enterprises. *Pozharovzryvobezopasnost' = Fire and Explosion Safety*. 2025;34(1):59–69. (In Russ.). DOI: 10.22227/0869-7493.2025.34.01.59-69
2. Mkrtchyan L., Straub U., Giachino M., Kocher T., Sansavini G. Insurability risk assessment of oil refineries using Bayesian Belief Networks. *Journal of Loss Prevention in the Process Industries*. 2022;74:104673. DOI: 10.1016/j.jlp.2021.104673
3. Makhutov N.A., Matvienko Yu.G., Romanov A.N., et al. Problems of strength, technogenic safety and structural materials science. Moscow: Lenand; 2018. 720 p. (In Russ.).
4. Grazhdankin A.I. Hazard analysis and risk assessment of major accidents in the oil, gas and coal industries. Doct. techn. sci. diss. Moscow: STC "Industrial Safety"; 2017; 340 p. (In Russ.).
5. Shargatov V.A., Sumskoi S.I., Pecherkin A.S. Simulation of gas release from pipelines using a new numerical method based on the Godunov approach. *Journal of Physics: Conference Series*. 2019;1205:012050. DOI: 10.1088/1742–6596/1205/1/012050
6. Oksman V.S., Tkachenko V.M., Fomintsova A.V., Grazhdankin A.I. On the methodological support for improvement of the state supervision over industrial safety conditions at objects of mining, metallurgical productions, and explosives in use. *Bezopasnost' truda v promyshlennosti = Occupational Safety in Industry*. 2024;(5):26–35. (In Russ.). DOI: 10.24000/0409-2961-2024-5-26-35
7. Poroshin A.A., Udavtsova E. Yu., Bobrinev E.V., et al. Assessment of fire hazard level of industrial objects based on the statistical methods. *Bezopasnost' truda v promyshlennosti = Occupational Safety in Industry*. 2020;(3):12–17. (In Russ.). DOI: 10.24000/0409-2961-2020-3-12-17
8. Vishnevsky V.P., Matyushin A.V., Stel'makhova N.V. Tax regulation of economic growth in the context of post-crisis recovery: Problems and prospects. *Studies on Russian Economic Development.* 2025;36(1):66–76. DOI: 10.1134/S 1075700724700539 (In Russ.: *Problemy prognozirovaniya.* 2025;(1):109–123. DOI: 10.47711/0868-6351-208-109-123).
9. Denisov A.N., Poroshin A.A., Danilov M.M., et al. The genesis of development, modern realities of scientific, methodological and normative legal substantiation of the concepts of "large fire", "complex (protracted) fire". *Pozharovzryvobezopasnost' = Fire and Explosion Safety*. 2025;34(2):5–19. (In Russ.). DOI: 10.22227/0869–7493.2025.34.02.5–19
10. Akimov V., Bedilo M., Derendiaeva O., Ivanova E., Oltyan I. Forecast of natural emergency situations with modern methods. *Reliability: Theory & Applications.* 2022;17(4):71–77. DOI: 10.24412/1932-2321-2022-470-71-77
11. Akimov V., Ivanova E., Oltyan I.S. Statistical models for forecasting emergency situations of a biological and social character. *Reliability: Theory & Applications.* 2023;18(4):41–45. DOI: 10.24412/1932-2321-2023-476-41-45
12. Cheng J., Greiner R., Kelly J., Bell D., Liu W. Learning Bayesian networks from data: An information-theory based approach. *Artificial Intelligence*. 2002:137(1–2):43–90. DOI: 10.1016/S 0004–3702(02)00191–1
13. Bochkov A. Reflections on dual nature of risk. Toward a formalism *Reliability: Theory & Applications*. 2023;18(S 5):44–74. DOI: 10.24412/1932-2321-2023-575-44-74
14. Gvozdev E.V. Intersystem interaction and relationships in the integrated safety system designed to prevent accidents and fires at explosion- and fire-hazardous enterprises. *Bezopasnost' truda v promyshlennosti = Occupational Safety in Industry*. 2024;(12):40–46. (In Russ.). DOI: 10.24000/0409-2961-2024-12-40-46
15. Blumberg V.A., Glushchenko V.F. Which solution is better? The method of prioritization. Leningrad: Lenizdat; 1982. 160 p. (In Russ.).
16. Saaty T.L. Decision making for leaders: The analytical hierarchy process for decisions in a complex world. Maastricht: Lifetime Learning; 1982. 291 p. (Russ. ed.: Saaty T. Prinyatie reshenii. Metod analiza ierarkhii. Moscow: Radio i svyaz'; 1993. 320 p.).

17. Bellman R.E. Introduction to matrix analysis. New York, NY.: McGraw-Hill, Inc.; 1966. 360 p. (Russ. ed.: Bellman R. Vvedenie v teoriyu matrits. Moscow: Nauka; 1976. 352 p.).
18. Belikov A.B., Simonyan V.V. Mathematical processing of geodetic measurement results. Moscow: Moscow State University of Civil Engineering; 2016. 432 p. (In Russ.).
19. Alamdari A.M., Jabarzadeh Y., Adams B., Samson D., Khanmohammadi S. An analytic network process model to prioritize supply chain risks in green residential megaprojects. *Operations Management Research*. 2023;16(1):141–163. DOI: 10.1007/s12063-022-00288-2
20. Anokhin A.M., Glotov V.A., Paveliev V.V., Cherkashin A.M. Methods for determining coefficients of criteria importance. *Avtomatika i telemekhanika = Automation and Remote Control.* 1997;(8):3–35. (In Russ.).
21. Gvozdev E.V. The development of assessment model of personnel's influence on the condition of the integrated safety system established at production plants. *Bezopasnost' truda v promyshlennosti = Occupational Safety in Industry*. 2024;(2):7–15. (In Russ.). DOI: 10.24000/0409-2961-2024-2-7-15

ABOUT THE AUTHOR

Evgeny V. Gvozdev — Cand. Sci. (Tech.), Assoc. Prof. of the Department of Mechanization, Automation and Robotics in Construction, Moscow State University of Civil Engineering, Moscow, Russian Federation
https://orcid.org/ 0000-0002-3679-1065
evgvozdev@mail.ru

Conflicts of Interest Statement: The author has no conflicts of interest to declare.

The article was submitted on 07.07.2025; revised on 13.10.2025 and accepted for publication on 25.11.2025. The author read and approved the final version of the manuscript.