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ORGANIZATIONAL AND METHODOLOGICAL ASPECTS OF MANAGEMENT OF ECONOMIC CONSEQUENCES OF TECHNICAL RISKS

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Abstract. A methodological approach to the assessment of technical risks of an industrial enterprise based on logistics is determined and substantiated and it is recommended as a monitoring tool for risk events and their economic consequences, as well as the choice of technical risk management activities to minimize losses. Scientific novelty of the obtained results consists of the substantiation of theoretical and methodological provisions, practical recommendations about mechanisms for managing economic consequences of technical risks in micrologistics systems. *The purpose of research* is to generalize and improve scientific and methodological bases of management of technical risks of a micrologistics system of industrial enterprise and to develop tools and practical recommendations for assessing their economic consequences. In order to achieve the stated purpose, the following tasks are formulated and solved: to improve classification of economic consequences of technical risks in micrologistics systems; develop a system of management of technical risks' economic consequences; improve mechanisms for assessing and forecasting economic consequences of technical risks. *The theoretical and methodological basis* of research is conceptual provisions and scientific developments of specialists on risk management issues published in monographs, periodicals, materials of scientific and practical conferences on the research topic. The tasks are solved by using general scientific and special methods, mathematical modelling methods based on a system approach. *Results.* The system of management of economic consequences of technical risks is substantiated that is a set of interconnected in time and space elements (subsystems) and their components, integrated into a certain integrity, and has a specific organizational structure, a set of economic methods, standards, models, and indicators of the impact of technical risks on production and service processes, as well as directions of decision-making concerning minimization of economic consequences of technical risks. Unlike existing tools that allow assessing technical risks as an indicator of equipment reliability, the proposed system provides economic component in addition to technical one by means of thorough evaluation of technical risks' economic consequences on a single methodical basis by material flows and on the whole by the micrologistics system, provides increased efficiency, multivariance, and adequacy of calculations of the technical and economic and financial planned indicators of the enterprise. The main components of the system for managing the economic consequences of technical risks are: a mechanism for evaluating the economic consequences of technical risks that occurred in the reporting period; mechanism of forecasting the economic consequences of technical risks; monitoring of the economic consequences of technical risks of micrologistics system, which is a methodological diagnostic tool, created within the operating information system of the enterprise and provides continuous monitoring of technical risk objects, analysis and control over the indicators of their activities and the impact on financial results of micrologistics system under uncertainty. *Practical implications.* Mechanism for evaluating the economic consequences of technical risks allows determining actual costs and losses associated with the failure of equipment for all elements of the micrologistics system (from a single object to logistics flows) on a unified methodical basis, to create an information base for forecasting the level of technical risk and its economic consequences in the planned period in the conditions of monitoring, to substantiate adequate methods of management of the economic consequences of technical risks. Fuzzy model of the choice of activities is based on fuzzy production rules that reflect the scale of the ENTR and the level of TP. Fuzzy model of the choice is based on production rules that reflect the scale of ECTR and the level of TR. At the entrance to this model, the level of risk and the level of economic consequences, and at the exit – the class of activities that need to be adopted before implementation.

Key words: economic consequences of technical risks, monitoring, equipment, system of management of economic consequences of technical risks, metallurgical enterprises.

JEL Classification: C53, G22, G31, G32

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1. Introduction

Modern conditions of economic activity of industrial enterprises of Ukraine are characterized by a high level of risk, the source of which is the external environment, as well as production activity. A special role belongs to the production risk, and in its composition – to the technical risk, the objects of which are available equipment. Management of technical risks and their economic consequences becomes an integral part of modern management, first of all, for enterprises of ferrous metallurgy. The target component of the technical risk is the economic consequences, which optimization means to minimize losses and costs in the places where they occur and maximize profits or minimize the damage to the entire micrologistics system.

The reduction of losses from technical risks in ferrous metallurgy is hampered by both the state of equipment and the lack of a systematic approach to the management of technical and repair services, as well as the imperfection of methodological and information support for the assessment of technical risks in the manufacturing sector. Existing methods and tools for risk management are used fragmentarily, mainly over the lack of the theoretical and methodological framework and practical application adapted to the domestic conditions. In such a situation, the need to improve organizational and methodical tools for managing the economic consequences of technical risks as a component of risk management system is rapidly increasing, which determines the relevance of this study.

At the same time, debatable are important issues concerning the separation of technical risks from the totality of production ones, the definition of its essence and significance, the ambiguity of methodological approaches to the assessment. Technical risks are usually investigated by technical specialists in the design and operation of equipment, and they are identified as a probability of failure of equipment during the operation of a production enterprise. The inadequacy of the study of links between the causes and the economic consequences of technical risks leads to inaccurate predictions and errors in determining the economic performance of economic entities.

Recently, in the domestic and foreign practice, the logistics management concept has become popular. The need to use a logistic approach is related to the evolution of the management process in the conditions of uncertainty and peculiarities of production processes of enterprises of ferrous metallurgy. Information and methodological support for existing risk management systems, as well as organizational problems of their functioning, do not create conditions for ensuring the effectiveness of management decisions regarding the minimization of losses from technical risks.

The presence of the abovementioned problems substantially limits the possibility of practical use of existing methodological tools and necessitates the improvement of the theoretical and methodological basis for evaluating the economic consequences of technical risks in order to increase the effectiveness of making managerial decisions and indicates the relevance of the chosen topic.

2. Recent research analysis and problem statement

The analysis of scientific publications on the decision-making problem in terms of uncertainty showed that the majority of scientific works widely consider theoretical issues of analysis of economic risk in general, as well as specific risks: banking, commercial, currency, credit, financial, strategic, political, etc. Special mathematical methods and models designed to assess the likelihood of occurrence of adverse events of a risky nature in the economy are developed.

The bibliography of scientific publications devoted to the study of risk management issues is extremely large and has over a thousand titles. These are the works of foreign and domestic scholars: I.T. Balabanov, S.V. Valdaitsev, V.V. Vitlinskyi, V.M. Hranaturov, A.I. Yastremskyi, and others. They considered the nature of the risk, determined the factors and causes of its occurrence, the characteristics of methods for assessing the degree of risk.

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3. The purpose and tasks of research

The purpose of research is to generalize and improve scientific and methodological bases of management of technical risks of a micrologistics system of industrial enterprise and to develop tools and practical recommendations for assessing their economic consequences.

In order to achieve the stated purpose, the following tasks should be solved:
– to formulate a generalized classification of economic consequences of technical risks in micrologistics systems;
– to develop a system of management of technical risks' economic consequences;
– to improve mechanisms for assessing and forecasting economic consequences of technical risks.

4. Materials and methods of studying the system of management of the economic consequences of technical risks

All technical risk objects of the micrologistics system cover a large number of technological equipment, each of which has its own peculiarities and specifics. The efficiency of the technological equipment is characterized by the following indicators: accuracy, productivity, capacity, the coefficient of efficiency, serviceability, and operational reliability. These indicators depend to a great extent on the degree of wear of parts and determine its technical condition. Metallurgical equipment has its own characteristics, and in the analysis of reliability, all its components (parts) are divided into groups. The first group includes parts whose failure (violation of technical conditions) does not affect the operation of equipment (deformation of the casing, change in the colour of the surface, etc.). Failure of these elements can be considered in isolation from the micrologistics system. The second group includes parts, the reliability of which for a certain time almost does not change (frames and body parts, low-volunteered elements with large reserves of strength). The third group includes parts, which repairs or adjustments are possible during the equipment operation or during its stop, without affecting its efficiency (debugging and replacement of the tool). The fourth group includes parts, which fail leads to equipment failures.

Technical risks and their economic consequences, occurring at all stages of the lifecycle of equipment and in any unit, cause the possible losses of the entire micrologistics system of the enterprise, and their minimization is a criterion for ensuring the efficiency of production. An adequate assessment of technical risks and their economic consequences can increase the validity of managerial decisions regarding the choice of activities aimed at reducing the frequency of occurrence of risk events and the magnitude of possible losses.

At the heart of managing the economic consequences of technical risks is the purposeful organization of work to reduce the possible risk, minimize losses at the onset of a risk event, as well as the search for ways to receive or increase income (profit) in an uncertain economic situation.

A generalized classification model of the economic consequences of technical risks is created based on the developed separate classifications of technical risks and their economic consequences (Figure 1).

The proposed systematization of economic consequences and directly risk events is intended for construction and use of the system of management of economic consequences of technical risks in order to increase the validity of the methodology of estimating losses and their impact on the financial and economic performance of enterprises under uncertainty. The developed structure of the management system for the economic consequences of technical risks is shown in Figure 2.

The system of management of economic consequences of technical risks is a set of interconnected in time and space elements (subsystems) and their components, integrated into a certain integrity, and has a specific organizational structure, a set of economic methods, standards, models, and indicators of the impact of technical risks on production processes and service, as well as decision-making directions for minimizing economic consequences in order to ensure the effective functioning of the micrologistics system of the enterprise under uncertain conditions. Unlike existing tools that allow assessing technical risks as an indicator of equipment reliability, the proposed system provides economic component in addition to technical one by means of thorough evaluation of technical risks' economic consequences on a single methodical basis by material flows and on the whole by the micro-logistic system, provides increased efficiency, multivariance, and adequacy of calculations of the technical and economic and financial planned indicators of the enterprise.

The first component of the proposed system is a mechanism for assessing the economic consequences of risk events that occurred during the reporting period (Figure 3).

The methodical mechanism for assessing the economic consequences of risk events as an element of the enterprise risk management system is understood as the internal organizational structure of the subsystem of management of objects of technical risks, characterized by a certain set of states of operation (work, refusal), actions, and processes aimed at changing the state of objects in order to minimize losses. The result of the operation of the mechanism is the management decisions to implement activities to minimize the economic consequences of technical risks.

5. The mechanism for assessing the economic consequences of technical risks

The mechanism for assessing the economic consequences of technical risks includes the following steps: qualitative analysis of risk events, calculation of direct losses and expenses of a single object for each event, estimation of economic consequences of technical risks, calculation of coefficients of technical risks, calculation

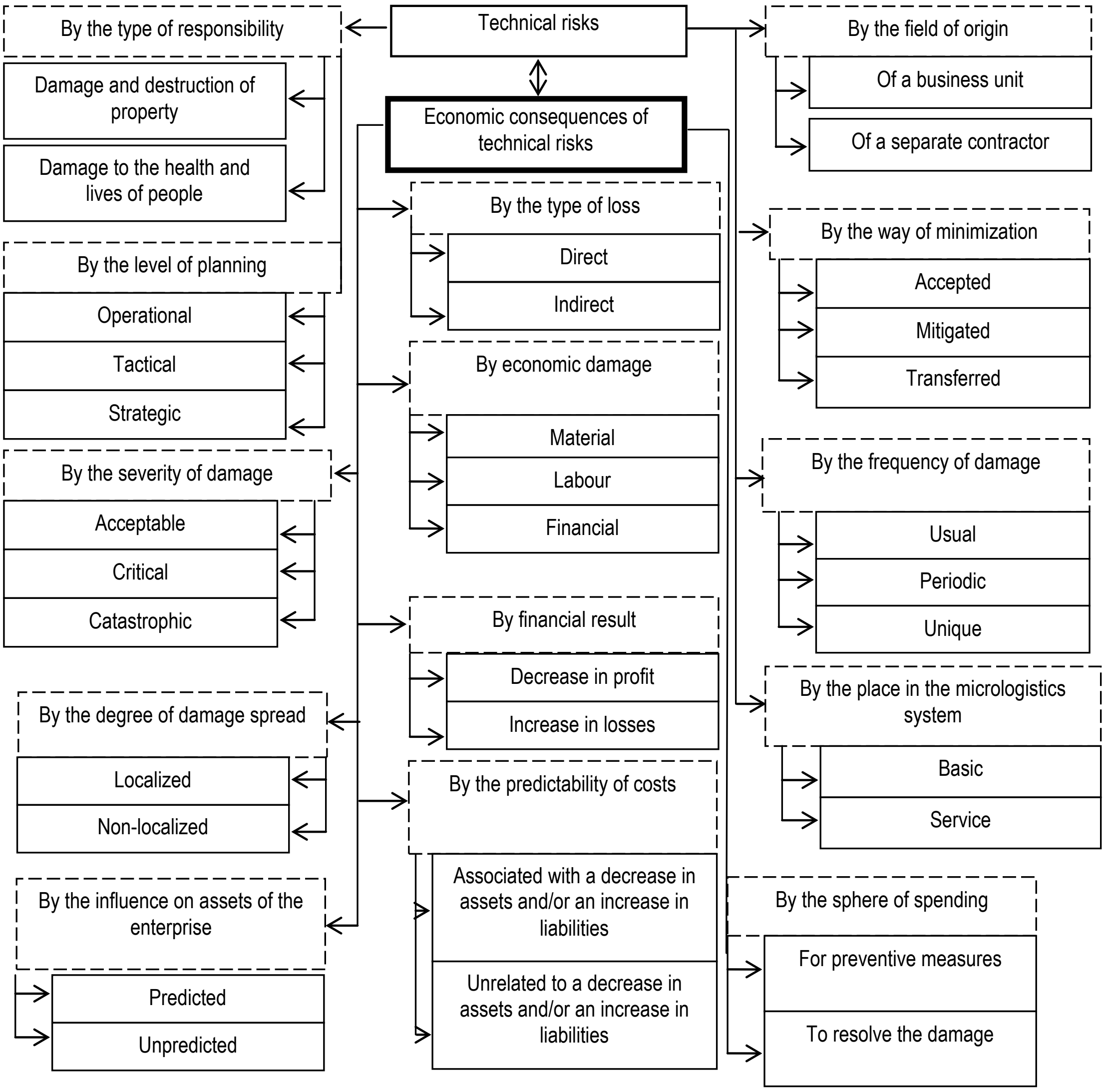

Figure 1. Classification of the economic consequences of technical risks

of statistical characteristics of technical risks of the micrologistics system of the reporting period, selection of techniques for managing technical risks.

Stage I. Qualitative analysis of risk events. Investigation of a risk event, that is, the occurrence of a technical risk identifies the events (destruction, damage, simple) by the specialists of the enterprise in the places of occurrence of damage and preliminary estimation of the scale of losses, the identification of causes and perpetrators.

Information on the size of economic consequences is general information and contains information about: direct losses associated with equipment failures; indirect losses, expressed by loss of income and increase in operating expenses in relation to the settlement of risk events; damages related to liability to third parties; damages related to the life and health of the personnel.

Stage II. Statistical characteristics of technical risks of the micrologistics system of the reporting period. The main characteristics of technical risk by objects (single, complex, material flows, micrologistics system) are the frequency of risk events and the severity of damage. Frequency (probability) is determined by the ratio of the total number of risk events that arose in the total number of technical risk objects. The relative severity of damage (the severity of loss) U is defined as the ratio of the total actual damage to the risk object Sp to the maximum possible Smax. The maximum damage can be estimated as the residual and market value of the risk objects of the micrologistics system. These indicators are used in conjunction with the technical risk factors for the ranking of objects when substantiating technical risk management techniques and selecting preventive activities when planning in the conditions of the monitoring system.

Stage III. Calculation of actual damage to a single object for each event. For a single entity, direct losses are economic outcomes (EH_{Φ}) that are determined by the

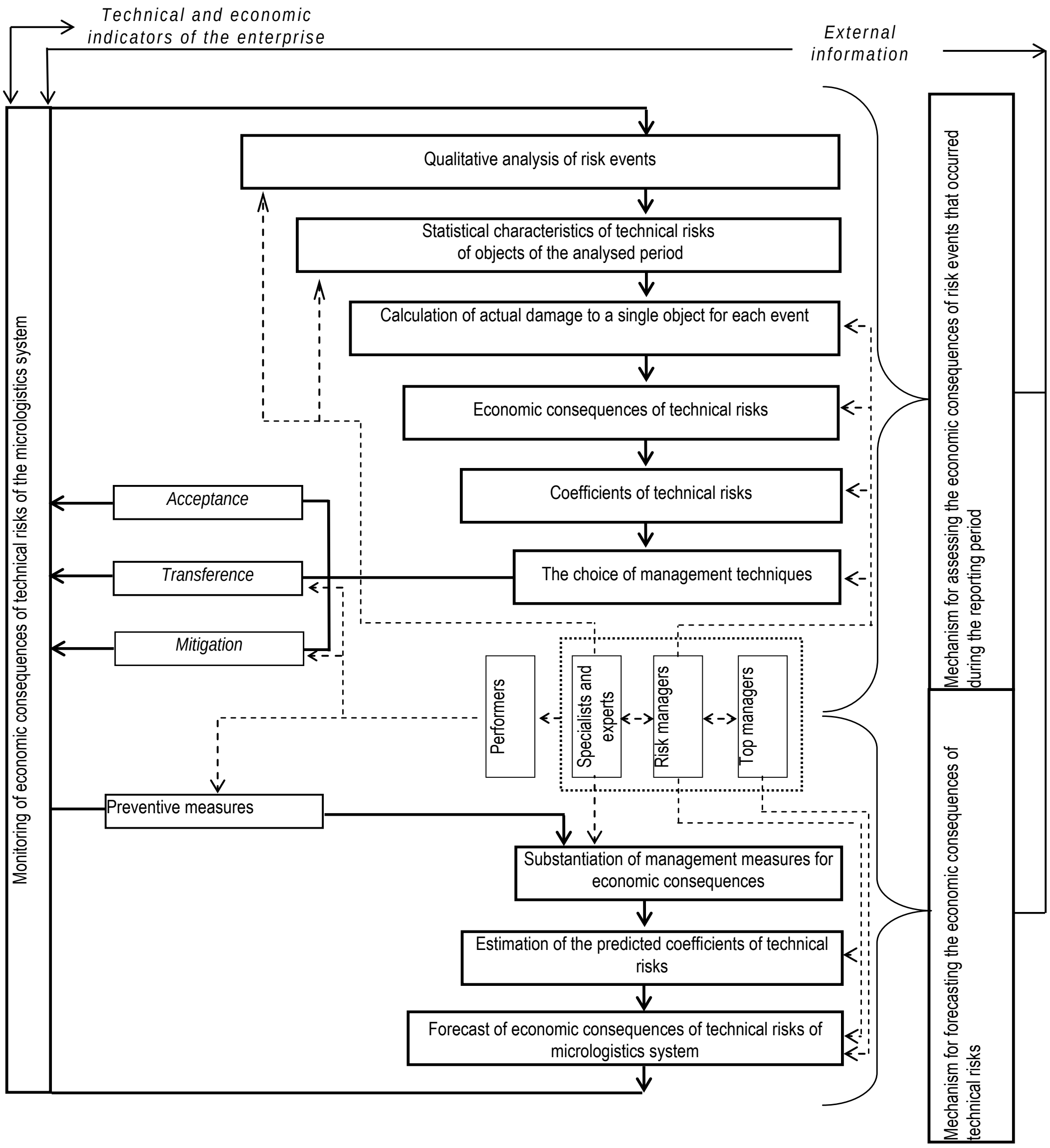

Figure 2. Structure of management system for economic consequences of technical risks

direct calculation of the amount of losses from technical risk and additional compensatory costs (formula 1).

$$EH_{\Phi} = V_{\phi} + V_{mp} + V_{np} + V_{комп} + V_{soc}, \quad (1)$$

where V_{ϕ} – total actual loss due to direct losses, UAH; V_{mp} – actual losses as a result of increased cost (increase of conditionally constant costs per unit of output) with a decrease in production in case of equipment failures, UAH; V_{np}. – costs for preventive measures in the reporting period, UAH; $V_{комп}$ – costs for compensatory measures in the reporting period, UAH; V_{soc} – socio-economic losses (payment for personnel for equipment downtime, payment for injured personnel, and so on);

Total actual losses as a result of direct losses over technical risks that have been occurred are estimated as the amount of direct damage in places of origin, as well as non-localized losses outside the technical risk object (other elements of the logistics chain, external environment).

$$V_{\phi} = \sum_{1}^{n} v_i, \; n = 1, 2, \ldots N, \quad (2)$$

where v_i – actual losses for the i-th case, UAH; N – the number of cases;

The increase in the cost of production by increasing the conditional-constant costs of a unit of production with the reduction of production (V_{mp}) determine the amount of lost profits that could be obtained by the enterprise in the absence of downtime in the event of equipment failure (formula 3):

$$V_{mp} = \sum_{i=1}^{n} P * T_i(ц - c), \quad (3)$$

where T_i – downtime due to technical risks in the reporting period, hours; P – average weighted productivity of the object, t/h; $ц$ – the average price of products to be produced, UAH/t; c – the average cost of production to be produced, UAH/t; n – the number of cases;

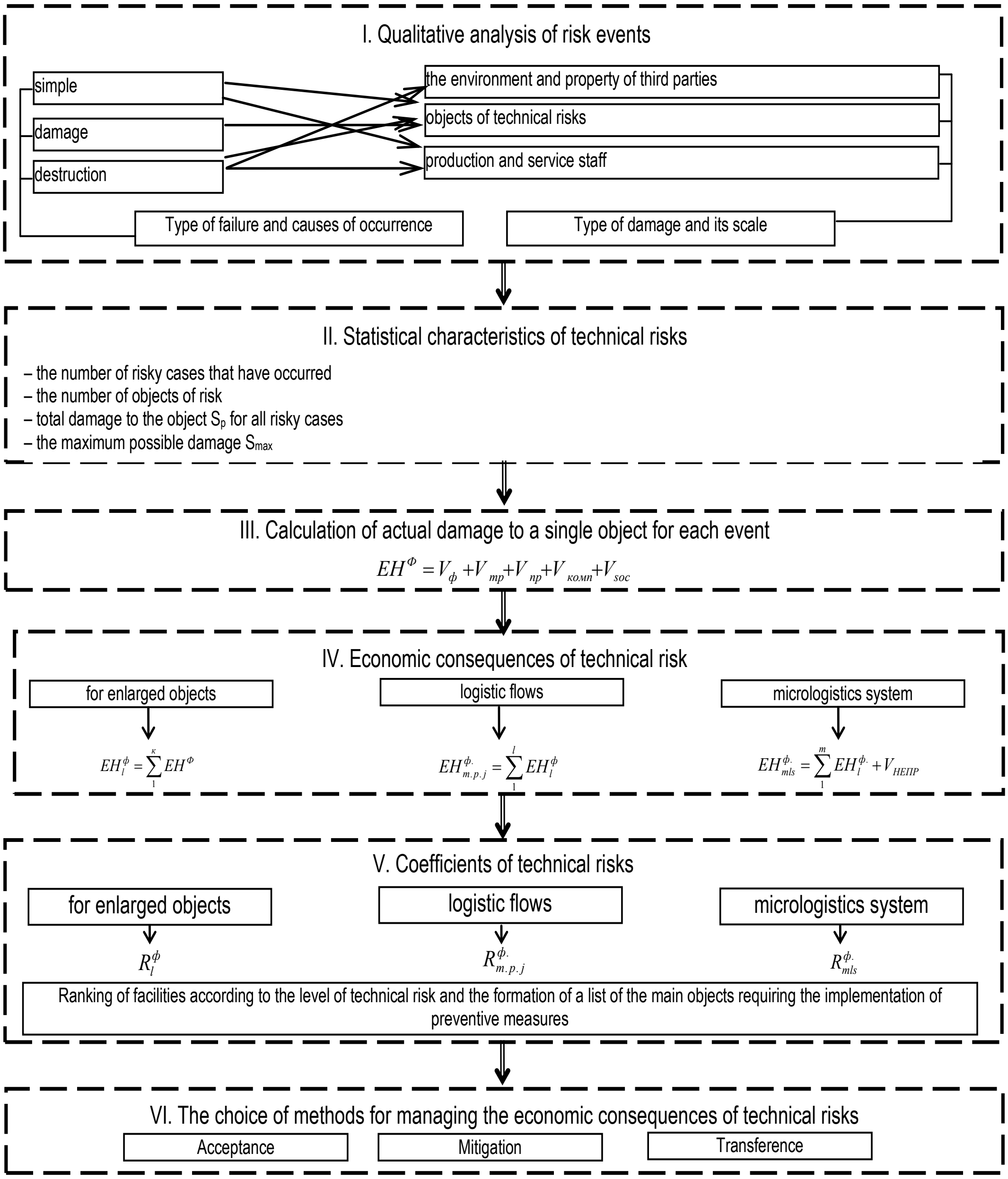

Figure 3. The mechanism for assessing the economic consequences of risk events

Costs for preventive measures consist of those provided for and those not provided for by the applicable technical and organizational regulations of the enterprise, i.e. normalized and unnormalized (formula 4):

$$V_{пр} = v_{норм} + v_{ненорм}, \tag{4}$$

where $v_{норм}$ – costs for preventive measures provided for by applicable technical and organizational regulations; $v_{ненорм}$ – costs for preventive measures not provided for by applicable technical and organizational regulations;

The cost of the compensation measures consists of the costs associated with the equipment damage ($v_{пош}$) and the costs associated with the destruction of the equipment ($v_{руйн}$):

$$V_{ком} = v_{пош} + v_{руйн}, \tag{5}$$

The costs associated with the repair of the damaged object ($v_{пош}$) consist of material, labour, and financial costs (formula 6).

$$v_{пош} = v_{мат} + v_{труд} + v_{фін}, \tag{6}$$

where $v_{мат}$ – costs associated with the purchase of spare parts and components, auxiliary materials, fuel, energy; $v_{труд}$ – wages of own workers, engaged in repair; $v_{фін}$ – payment for services for the repair of third-party organizations;

Expenses related to the restoration of a destroyed object ($v_{руйн}$) are calculated by formula 7.

$$v_{руйн} = v_{демон} + v_{інв}, \tag{7}$$

where $v_{демон}$ – expenses for dismantling of the destroyed object, UAH; $v_{інв}$ – current expenses and (or) investments for the restoration of the destroyed object.

If the recovery of an object cannot be carried out at the expense of current expenses, then the investment is necessary. Investments for the restoration of a destroyed object may be made at own expense (using a part of the profit or special funds for output expansion); at the expense of borrowed funds (attraction of third-party investors); at the expense of loan proceeds (obtaining a loan from a bank or another financial institution or issuing bonds for a particular investment or innovation project).

Socio-economic losses (payment for personnel for equipment downtime, payment for injured personnel, and so on) are determined by formula 8:

$$V_{soc} = v_{економ.} + v_{соц}, \quad (8)$$

where $v_{економ.}$ – salary of employees for an idle time due to technical risks; $v_{соц}$ – payments for injury as a result of technical risk to people (payment of assistance for temporary disability to victims, social assistance and compulsory payments and fines provided by law).

Actual economic consequences of single objects are used to assess the economic consequences of technical risks of aggregated objects, logistics flows, and the micrologistics system as a whole.

Stage IV. Economic consequences of technical risks. At this stage, the economic consequences of technical risks are calculated for the aggregated objects, material flows, and the micrologistics system. The economic consequences of technical risks for aggregated objects (link, shop, division) of the reporting period are calculated by formula 9:

$$EH_l^{\phi} = \sum_{1}^{\kappa} EH^{\Phi},\ k = 1, 2, \ldots K, \quad (9)$$

where K – the number of single objects in the m-th aggregated object of technical risk.

The economic consequences of technical risks for material flows are calculated by formula 10:

$$EH_{m.p.j}^{\phi.} = \sum_{1}^{l} EH_l^{\phi},\ l = 1, 2, \ldots L, \quad (10)$$

where L – the number of aggregated objects of technical risk by the j-th material flow.

The economic consequences of technical risks for the micrologistics system are calculated by formula 11:

$$EH_{mls}^{\phi.} = \sum_{1}^{m} EH_{m.p.j}^{\phi.} + V_{НЕПР},\ m = 1, 2, \ldots M, \quad (11)$$

where M – the number of material flows in the micrologistics system; $V_{НЕПР}$ – costs for compensation for indirect damage that has arisen outside the object of technical risks (environment, third party property).

Indirect costs associated with damages outside the micrologistics system are carried out in accordance with applicable laws or court decisions.

$$V_{НЕПР} = v_{серед} + v_{ос} + v_{майн} + v_{мор}, \quad (12)$$

where $v_{серед}$ – costs of compensation for damage caused by the technical risk to the environment; $v_{ос}$ – costs of compensation for damage caused by the technical risk to the life and health of third parties; $v_{майн}$ – costs of compensation for damage caused by the technical risk to the property of third parties; $v_{мор}$ – costs of compensation for moral damage as a result of technical risk in the event of a court decision.

The methodology of estimating the economic consequences of technical risks of the micrologistics system developed by the author allows ensuring monitoring of the state of technical risk objects and determining the coefficients of technical risks for material flows and the micrologistics system as a whole.

Stage V. Coefficients of technical risks. The calculation of the coefficients of technical risks is performed by the aggregated objects R_l^{ϕ} (formula 13), by material flows $R_{m.p.j}^{\phi}$ (formula 14), and the micro-logistic system as a whole R_{mls}^{ϕ} (formula 15).

The calculation of the coefficients of technical risks by the aggregated objects is defined as the ratio of the actual EH_l^{ϕ} for an aggregate object to the maximum possible direct loss.

$$R_l^{\Phi} = \frac{EH_l^{\phi}}{S_{\max}}, \quad (13)$$

where $S_{\max}$ – the maximum possible direct damage to an aggregated object. The maximum damage may be limited to both the residual and market value of the object.

The coefficient of technical risks of aggregated objects is used to rank objects according to the severity of the damage and to create a list of the main objects requiring implementation of measures to minimize the technical risk.

$$R_{m.p.j}^{\phi} = \frac{EH_{m.p.j}^{\phi.}}{EH_{m.p.j}^{\phi.} + \Pi_{m.p.j}^{\phi}}, \quad (14)$$

where $\Pi_{m.p.j}^{\phi}$ – actual profit by j-th material flow;

$$R_{mls}^{\phi} = \frac{EH_{mls}^{\phi.}}{EH_{mls}^{\phi.} + \Pi_{mls}^{\phi}}, \quad (15)$$

where Π_{mls}^{ϕ} – an actual profit of the micrologistics system.

The coefficients of technical risks are used for the systematic evaluation of the technical condition of the equipment for all elements of the logistic chain, material flows (formula 14), and the micrologistics system as a whole (formula 15), which ensures the integration of its individual parts at the technical, technological, economic, methodological levels from the position of the only logistical approach. The coefficients of the technical risks of the micrologistics system are an indicator of the assessment of equipment reliability dynamics. Detection of trends in the dynamics of technical risks by using these coefficients will increase the efficiency and adequacy of the selection of activities and the accuracy of the forecast of the impact of these activities on the financial performance of the enterprise in terms of uncertainty.

Stage VI. The choice of methods for managing the economic consequences of technical risks. The main

Table 1
Regulatory information for the identification of technical risks and the choice of methods for managing economic consequences and activities to minimize them

Type of technical risk	Range of quantitative risk assessment	Management method	Contents of events
Catastrophic	(R > Rпор.кат)	Transference	Compulsory insurance of objects of particularly dangerous technical risk
		Acceptance	A conscious decision to take a risk without preventive measures and the need to compensate for loss at its own expense
Critical	(Rпор.крит < R ≤. Rпор.кат)	Transference	Transferring responsibility for risks to other entities (insurance companies, outsourcers, etc.) without eliminating risk factors
		Mitigation	Elimination of risk factors, reduction of the probability of occurrence and (or) possible losses in case of equipment failures by introducing preventive measures and choosing the best solutions for compensation of damage (at the expense of capital expenditures)
Acceptable	(R ≤ Rпор.крит)	Mitigation	Elimination of risk factors, reduction of the probability of occurrence and (or) possible losses in case of equipment failures by introducing preventive measures and choosing the best solutions for compensation of damage (at the expense of current expenses)
		Acceptance	A conscious decision to take a risk without preventive measures and the need to compensate for loss at its own expense (current expenses)

techniques for managing technical risks and their economic consequences, according to the proposed classification (see Figure 1), are the acceptance, mitigation, transference. The basis for choosing one or another method of management is the scale of economic consequences: catastrophic, critical, admissible (see Figure 2).

Within the developed system, acceptable technical risks are regulated by accepting or mitigating, critical technical risks are regulated by transference or mitigation. The regulation of catastrophic risks, which by their nature are technogenic, is carried out at metallurgical enterprises through the transference to insurance companies licensed to carry out compulsory insurance in accordance with the current legislation.

The regulatory reference information for identifying technical risks and the choice of methods for managing economic consequences and activities for their minimization is given in Table 1. The thresholds of coefficients by type of risk are set specifically for each enterprise.

The most commonly used method of management of the economic consequences of technical risks in the process of ongoing production activities, prevention and settlement of losses is mitigation. This technique allows choosing and justifying activities to eliminate risk factors, reduce the likelihood of occurrence and losses in case of equipment failure. The main groups of mitigation activities within the developed management system are: organizational and technical; financial and contractual; innovative.

Measures selected on the basis of risk assessment can be directed immediately to reduce the risk, eliminate risk factors or reduce economic consequences. The choice of activities is a classification task performed for each identified technical risk and contains the following steps:

Stage 1. Construction of a model for assessing and selecting a class of activities.

To construct the model, the following components are determined:

– establish a compliance with the level of risk and classes of activities $K_{ij}^{зах}$ aimed at: reducing the risk R_i (class of activities $K_{i1}^{зах}$); elimination of risk factors (class of activities $K_{i2}^{зах}$); reduction of economic consequences (class of activities $K_{i3}^{зах}$);

– determine classes of activities $K_{ij}^{зах}$ and levels of influence respectively on reducing the risk R_i, eliminating risk factors.

– set conditions and mechanisms for selecting alternative classes of activities $K_{ij}^{зах}$ depending on the assessed level of risk and the scope of possible economic consequences.

Stage 2. Establishing the correspondence of risk levels and classes of activities to reduce them. Each level of risk R based on the expert procedure is brought into conformity with a class of activities that determines the degree of impact of activities of the separated group to reduce this risk in the system (Table 2).

Stage 3. Establishing conditions and mechanisms of the choice of activities $K_{ij}^{зах}$ depending on the level of technical risks and the scale of economic consequences.

Table 2
The correspondence of risk levels and classes of activities to reduce them

Technical risk	Class of activities			
	R_1	R_2	…..	R_n
Usual H_R	$K_{11}^{зах}$	$K_{21}^{зах}$	…..	$K_{n1}^{зах}$
Periodical C_R	$K_{12}^{зах}$	$K_{22}^{зах}$	…..	$K_{n2}^{зах}$
Unique B_R	$K_{13}^{зах}$	$K_{23}^{зах}$	…..	$K_{n3}^{зах}$

The condition for selecting an alternative class of activities is to assign the value of the output variable R_i to one of the three classes H_R, C_R, B_R, taking into account the excess of some established threshold (for example, 0.5).

The correctness of this choice is ensured by observing the necessary requirements when constructing a model for assessing technical risks. In addition to the level of risk, the choice of a class of activities is affected by the scale of economic consequences.

The fuzzy model of the choice of activities proposed is based on fuzzy production rules that reflect the extent of the economic consequences of technical risks and the level of technical risk.

For all R_i, the following stages of economic consequences are given:

$$EH_i = \{Acceptable(H_{EH}), Critical(C_{EH}), Catastrophic(B_{EH})\}.$$

Then the compliance of the risk levels taking into account the economic consequences and classes of activities can be established on the basis of rules of the following type:

$\Pi_1 : IF \ (R_i \ is \ H_R) \ AND \ (EH_i \ is \ H_{EH})$,
THEN class of activities is not selected;

$\Pi_2 : IF \ (R_i \ is \ H_R) \ AND \ (EH_i \ is \ C_{EH} \ or \ B_{EH})$,
THEN class of activities $K_{i1}^{зах}$ is selected;

$\Pi_3 : IF \ (R_i \ is \ C_R) \ AND \ (EH_i \ is \ H_{EH})$,
THEN class of activities is not selected;

$\Pi_4 : IF \ (R_i \ is \ C_R) \ AND \ (EH_i \ is \ C_{EH} \ or \ B_{EH})$,
THEN class of activities $K_{i2}^{зах}$ is selected;

$\Pi_5 : IF \ (R_i \ is \ B_R) \ AND \ (EH_i \ is \ B_{EH})$,
THEN class of activities is not selected;

$\Pi_6 : IF \ (R_i \ is \ B_R) \ AND \ (EH_i \ is \ C_{EH} \ or \ H_{EH})$,
THEN class of activities $K_{i3}^{зах}$ is selected.

Stage 4. Constructing a fuzzy model of choosing a class of activities in the form of a fuzzy classifier.

The main advantage of fuzzy classification is the possibility of formulating reliable classifications based on incomplete and not entirely reliable incoming parcels. The structure of the fuzzy model for choosing a class of activities in the form of a neuro-fuzzy classifier is shown in Figure 4.

Fuzzy classifier consists of the following layers:

Layer 1. At the exit of elements of this layer, the degrees of belonging of the input variables (the level of technical risk and the degree of economic consequences) to the corresponding fuzzy sets are formed, that is: "low", "medium", "high".

Layer 2. Elements of this layer are intended to formulate components of the statements and preconditions of the rules.

Layer 3. Elements of the layer, the number of which corresponds to the number of rules (Π) after optimizing the basis of fuzzy rules.

Layer 4. Elements of this layer perform a weighted accumulation of values with the release of elements of layer 3 and carry out operations on the feasibility of choosing each activity based on its economic efficiency.

Layer 5. The values at the outputs of this layer are used to select one of the classes of activities $K_{i1}^{зах}$, $K_{i2}^{зах}$, $K_{i3}^{зах}$ with the degree of the expediency of choosing the appropriate class of activities. As a decision, choose a class with the most appropriate class of belonging.

Thus, implementing a fuzzy model for assessing the choice of a class of activities based on a neuro-fuzzy classifier allows not only determining a class of activities,

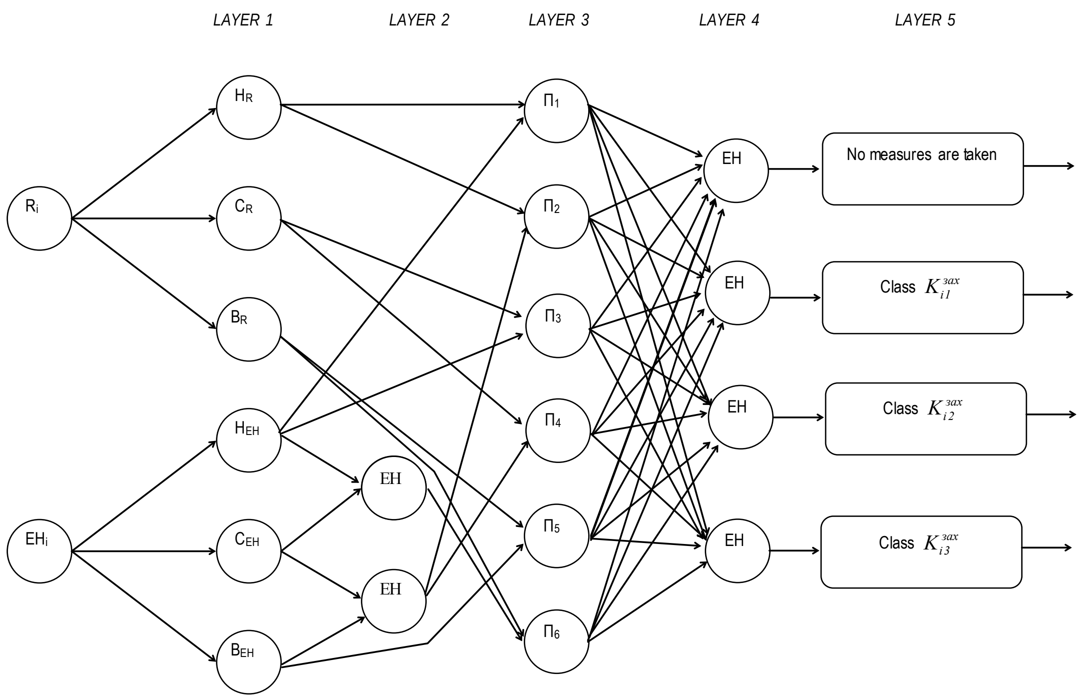

Figure 4. The structure of the fuzzy model of the choice of class of activities

corresponding to the level of technical risk and the degree of its economic consequences, but also assessing the degree of feasibility of such a choice.

The second component of the proposed system is the mechanism for forecasting economic consequences (Figure 2), which includes such a sequence of actions.

– substantiation of measures of management of economic consequences of technical risks;

– estimation of the forecast level of coefficients of technical risks;

– forecast of economic consequences of technical risks of the micrologistics system.

The reliability of the micrologistics systems is determined by the level of technical risk of all elements and is formed on the basis of careful selection of preventive measures financed at the expense of the enterprise or other sources. The criterion of the expediency of expenses to decrease technical risk is a correlation of additional expenses to increase reliability and reduce expected losses. Features of the dynamics of characteristics of the reliability of technological elements of the micrologistics system in terms of ensuring reliability and fail-safeness lead to the following conclusions:

– the characteristics of the reliability of single and duplicating equipment should be continuously monitored and analysed in order to timely detect critical moments of continued operation;

– minimization of losses in the case of preventive technical influences requires preparation for the necessary preventive and repair work in order to have at the time of their carrying everything necessary for the performance of work in the normative term;

– in cases where the equipment requires long-term repairs or is not subject to it, it is necessary to prepare backup equipment, to create reserves in order to prevent long-term stopping of the main production.

The methodical tool for diagnosing the economic consequences of technical risks, the actual assessment of damage at a risk event, is the monitoring subsystem (Figure 2), which is created within the operating information system of the enterprise and provides continuous monitoring of the technical risk objects, analysis and control of their performance indicators, and influence on financial results of the micrologistics system in conditions of uncertainty. The mechanism of monitoring the economic consequences of technical risks of the micrologistics system includes the following sequence of actions: technical and economic indicators of the enterprise are analysed, external information is taken and directed to the mechanism of economic consequences estimation and mechanism of forecasting of economic consequences. It is this mechanism that summarizes and processes information of management system of the economic consequences of technical risks.

The subject of management of the economic consequences of technical risks is a group of people, a unit or a specialist who implement risk management measures based on practical recommendations for the implementation of a mechanism at a particular enterprise, the purpose of which is to provide a reasonable management solution for optimizing the economic consequences of technical risks.

The organizational form of management of the economic consequences of technical risks at a particular enterprise is determined by the scale of production, strategic target settings, financial and information capabilities, as well as the state of the risk management system existing at the enterprise. The main organizational forms of management of the economic consequences of technical risks of enterprises, the choice of which in specific conditions is related to the scope of activities and strategy of risk management, are: the target department of risk management; special department of management of economic consequences of technical risks; a separate bureau (sector) in one of the divisions of the technical profile; a target team that brings together skilled professionals of various professions to manage economic consequences of technical risks and develop measures to minimize losses, and which independently plans and organizes its activities.

For large and medium-sized enterprises, it is expedient to create in the structure of the management apparatus a specialized unit – a department or a bureau of risk management. When organizing a risk management unit, one should adhere to certain principles. Firstly, the functions of control and decision-making on risks should be differentiated. Secondly, the risk manager needs direct access to senior executives in order to ensure a timely response to the risk situation. Thirdly, risk managers should always be aware of technical risks, that is, have direct access to the monitoring system. At small enterprises, management of all economic risks (including technical ones) is taken on by one of the key managers (head or his deputy), so only he can use a more effective form of risk management, for example, services of a profile consulting organization.

Regardless of the chosen organizational form of management, the economic consequences of technical risks, the sequence of actions, the availability of monitoring information by the persons who make management decisions for minimizing the consequences integrates the management system with the economic consequences of technical risks into the enterprise management structure.

6. Conclusions

The proposed management system for economic consequences of technical risk, in contrast to the existing ones, is directed to adequately assess the economic consequences (i.e., losses and costs) caused by risk events (equipment failures) and includes three mechanisms: estimating the economic consequences of the events occurred and the choice of methods to reduce them; forecasting the size of the expected economic consequences, taking into account preventive measures and assessing their impact on the financial result; monitoring subsystem, which allows to control actual and possible losses and additional costs for all elements of logistic flows and to make informed managerial decisions regarding the choice of measures to minimize the economic consequences of technical risks. The proposed mechanism of prediction of economic consequences of technical risks provides an adequate estimation of forecast indicators taking into account preventive measures and allows increasing the accuracy of calculation of planned financial and techno-economic indicators of activity of enterprises and their subdivisions under conditions of uncertainty, taking into account the influence on their fluctuations of losses and additional expenses which can arise at risk events.

The proposed methodology for estimating and predicting technical risks of objects is characterized by a multilevel system of hierarchically interdependent indicators: integral index of technical risk, complex index of technical risk of an aggregated object, through index of technical risk of the micrologistics system or its fragments. End-to-end assessment of technical risks of the micrologistics system (subsystem), in contrast to existing ones, is carried out by means of the vertical convolution of single or complex risk indicators for the objects of the main material flows (by production areas, by enterprises, by productions or by stages of the equipment lifecycle).

The expediency of using a fuzzy model for assessing the choice of a class of activities based on the neuro-fuzzy classifier is substantiated. The use of a neuro-fuzzy classifier in the implementation of a fuzzy model of assessment and selection of classes of activities allows, besides fulfilling the requirements formed to it, to adjust and adapt this model to changing conditions as a part of an integrated model of risk management in the process of monitoring, modelling of the dynamics of their management and analysis of possible scenarios for managing situation development.

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