

# Methodology of risk assessment and forms of environmental safety management for the transport of dangerous goods by railway transport

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**Abstract.** The authors examined the scientific basis for managing environmental and economic risks in the transport of dangerous goods by rail. The importance of optimizing the monitoring of environmental safety and the organization of environmental risk management was noted. The paper presents the interrelation of the functional strategy of ensuring the reliability of the transportation process with other strategies. A new functional strategy and a schematic diagram of the environmental management system for making management decisions to optimize environmental management in railway transport have been proposed. A conceptual apparatus has been developed to identify and determine environmental risks and the principle of their management during the transport of dangerous goods by railway transport.

## 1 Introduction

Modern society in its activities often goes into risks and unstable states that are associated with emergencies of different levels. Accordingly, there is a need to determine and predict potentially hazardous conditions and develop adequate methods for their management.

One of the important directions of the presented work is the development of strategies for managing environmental risks during transportation and handling hazardous products during railway transportation with the purpose of risks minimizing, which is one of the priorities of environmental safety on the railways today.

Ensuring a high level of environmental safety and, accordingly, minimizing environmental risks is based not only on the availability of certain tools and skills, but also on the ability to simulate the situation, predict its development and make decisions that are adequate the situation that has arisen.

One of the most important aspects of maintaining positive environmental performance of the railway transport is: to optimize the monitoring of environmental safety level and the management of environmental and economic risks [1-3].

## 2 Development of methodology for the organization of environmental activities on the railway transport

The development of relations between the society and the nature requires the use of new means of information

processing, which are grounds for the decision-making system ensuring environmental quality. In this case, information technology is considered as the most optimal tool. Under information technology we mean a set of methods, production, software and technological tools, integrated into the technological chain, which ensures collection, storage, processing, output and spread of information. At the same time environmentally sound solutions depend not only on the quality and quantity of information, but also on its prompt receipt.

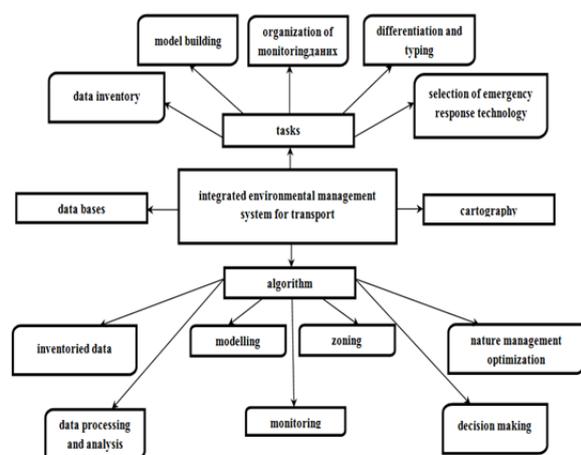
Statistics confirm that in recent years, due to intensive development of fundamental sciences (mathematics, probability theory, statistics, etc.), there were objective prerequisites for creation of methods for risk measuring based on the introduction of appropriate permissible measure.

The full-fledged solution of environmental management tasks in areas of dangerous products transportation, in particular, depends on the systematic analysis of a large number of heterogeneous data, as well as the solving a large number geographical, technological and industrial tasks (Fig. 1). Reliable and timely receipt of necessary information often plays a decisive role in the optimization of nature management, which is becoming extremely important in the context of intensification of transport complex development.

The development of environmental management systems during nature management organization on the basis of modern information technology will not only reduce the frequency of emergencies associated with pollution of environmental elements, but also optimize the organization of nature use, because high concentration of

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resources can lead to mutually exclusive types of anthropogenic activity in adjacent areas. In this case, the environmental management system is designed to identify the best options for environmental management, taking into account environmental and economic factors.



**Fig. 1.** Principal scheme of the integrated system for managing the environmental situation on transport.

In order to minimize the economic and environmental damage caused by traffic accidents during dangerous products transportation, special attention was paid to preventive measures, including simulation of emergency warning systems. The process of preventive system modeling for preventing railway accident occurrence and ensuring environmental safety during transportation includes the stage of a terrain model construction containing different layers of digital map information, including receptivity maps, as well as the model of dangerous goods behavior.

In addition, the analysis of the existing conceptual apparatus and the existing regulatory framework confirmed the need for harmonization of industry terminology in the gradation of occurrence of railway accidents with different degrees of severity and the national system of concepts. The system approach to this problem of assessment and management traffic accidents risks, in particular, during implementation of the technological process of dangerous goods transportation by the network of railways involves solving the two-stage task of stochastic programming:

- development of methods for quantification of risks of dangerous transport situations;
- development of mathematical models of emergency consequences on rail transport and the choice of rational measures to reduce the risks of their occurrence and the size of damage from emergencies that have already developed.

In this case, one of the priority tasks is to determine the degree of danger (degree of vulnerability) of objects and operations that are carried out during railway transport operation [5].

The degree of danger depends on the probability of danger occurrence and its intensity, which is determined by the degree of territory vulnerability.

The authors offer a term “the receptive status of the

object (vulnerability)” which is The receptive status of the object (vulnerability) is characterized by the magnitude of losses caused during fixed time by the action of a dangerous process of certain intensity on the territory or object. Vulnerability is an important component of a risk that affects its decline. For today, management is mainly limited to engineering protection of objects, rather than extending to the most dangerous processes management. Thus, the problems of risk management are reduced to managing the vulnerability of territories (objects) under the influence of dangerous processes.

The assessment of recipients’ vulnerability stems from the assumption of their possible partial damage as a result of a dangerous process. The receptive status of territories should be assessed, as a whole, in the territory and in the context of its separate regions. In existing techniques, the question of depicting territories specifics, in general, remains neglected.

The vulnerability of recipients (objects) can be evaluated according to recipients’ types, which makes the method universal and easy to use. To do this, first of all, it is necessary to determine a complete list of recipients in their most fractional classification on each area of action. The main recipients are usually: agriculture, forestry, communal household. The general scheme of analysis, assessment and management of environmental risk is as follows:

1. detection and prognosis of hazardous processes, their intensity, repeatability, area of action;
2. zoning of the territory;
3. assessment of the receptive status of objects;
4. prediction of the development of secondary synergetic hazards;
5. mapping of risks;
6. establishment of permissible levels of risk and decision-making on management.

The assessment of risk degree of processes and vulnerability of territories and objects is carried out on the basis of experimental and theoretical studies regarding the database of territories and objects receptive status during the event [5].

Thus, the receptive status of the object ( ) equals the degree of potential vulnerability of the object with its anthropogenic component.

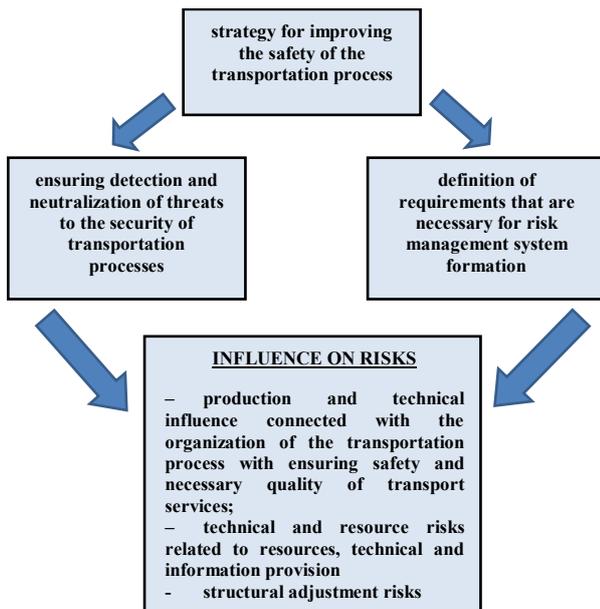
The risk, as the probability of a dangerous accident occurrence, can be classified according to various features: the sources of risks occurrence and the nature of risks’ consequences. The sources of risks include geological processes, seismic phenomena, human factor, financial instability, technical innovations and even political events. According to these sources, the risk is called geological, seismic, financial, innovative, and political. Thus, the safety criterion is the permissible level of risk.

### 3 Conceptual principles of ensuring environmental safety in the developed methodology

Environmental safety in the organization of hazardous products transportation by railway depends on the

reliability of engineering structures, compliance with established operating modes, the reliability of technological systems operation, organization and compliance with the established sequence of work and operations performance. Taking into consideration the performance of all works with the direct participation of specialists of different levels, the security of made decisions to a large extent depends on the skill and diligence of the staff.

The functional strategy of ensuring reliability of the transportation process should become the priority option for functioning all departments and units of transport infrastructure (Figure 2).



**Fig. 2.** Scheme to increase the level of safety of the transportation process by means of risk management [6].

To form a new functional strategy for improvement of transportation process safety, you need:

1. analysis of weak points of the existing functional strategy;
2. guarantee of the information reliability;
3. adaptation and processing of the regulatory base;
4. advanced training of the bodies of operational management and control;
5. constant control over regulatory requirements observance.

The analysis of the regulatory framework observation for ensuring safety processes on the railway revealed that the security was achieved so far, to a certain extent, by intensifying maintenance works, the growth of the number of unplanned repairs of rolling stock, the increase of the number of defectoscopists and other strategically incorrect steps. Maintaining stable position and transition to a guaranteed level of traffic safety should be based on the concept of “acceptable” risks.

The classification of hazard indicators on the railway transport should include two interrelated groups of danger indices characterizing the consequences of accidents (material and social damage) and probabilistic indices (the probability of an accident due to some risk factor, etc.).

It is established that according to available statistical information about dangerous transport situations and train crashes it is possible to evaluate only the compliance of indices of safety state of trains with the exponential distribution law with constant and variable intensity of accidents. During preparation of plans for railway lines and main railways for freight trains formation, which regulate trains traffic, and during dangerous goods transportation, in particular, the substantiated values of indicators that ensure traffic safety using the methodology of risk analysis and anthropogenic risks, in particular, are not taken into account. Thus, at present, there are no conditions for a reasonable comparative choice of routes that are acceptable according to their risk indicators and often are laid in densely populated areas.

Thus, the tasks have set and implemented the tasks of simplifying and improving the methodology for assessing (taking into account) the risks of transport accidents and economic losses of railway lines, separate territories and specific routes for dangerous goods transportation, with regard existing dangerous crossings with pipelines and motor transport, the presence of adjacent industrial and urban structures (in the areas of mass transshipment of oil cargo, in particular), as well as various factors of natural hazards.

From the standpoint of the natural component of risks, the following environmental factors must be taken into account: seismo-geological; showers, floods, flooding, storms (for coastal areas); hurricanes, tornadoes.

The necessity to account these types of natural hazards is due to the specifics of railway transport, which infrastructure damage should be timely determined and traffic on dangerous sections should be stopped. These under-predicted transient processes bear the main danger.

From the position of the technogenic component of risks for building maps, industry-specific accident data should be used. Technogenic risks include:

- risks of accidents due to non-normative technical condition of infrastructure elements;
- risks from interaction with communication networks at crossings;
- risks from interaction with motor highways at crossings.

The lack of a single method for assessing the damage caused by accidental spills of dangerous products (oil, gasoline, etc.) into environmental components, and methodological approaches for assessing the environmental risk of railway lines operation complicate the development of environmentally sound solutions to minimize the consequences of emergency situations for the environment.

The strategy of minimizing the impact on the environment should be aimed at applying methods for restoration of contaminated areas and liquidation of waste and soils that contain them [7].

In connection with it, there is a need to improve the state of ecological safety at the phase of emergency situations elimination during dangerous goods transportation, by solving optimization problem of

determining the optimal amount, location and the capacity of complexes, which technological support allows to process the entire volume of possible waste (petroleum products and substances of chemical industry, in particular) formed as a result of technological processes and emergency situations.

Taking into account all the above-mentioned aspects, the methodology for assessing ecological risk of accidents on railway transport during dangerous goods transportation on a heavy traffic route is proposed. Knowledge of the probability of emergency situations occurrence and the value of losses that they can inflict on the environment allows predict the magnitude of contaminated areas and the amount of waste generated during elimination of emergency consequences (the spill of dangerous goods).

One of the priority guidelines of existing and emerging theories of risks is the development of principles of managing them. For risk management we accept determination, development and implementation of measures to reduce the level of risks.

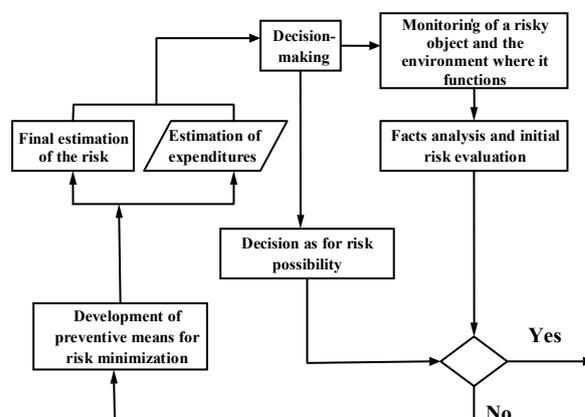
The scheme of developed risk management algorithm describes the procedure for finding an acceptable level of risks associated with dangerous natural and anthropogenic processes. In this scheme, the assessment of permissible risks is assumed in the decision-making block (Fig. 3).

The scientific basis for determining basic quantitative risk indicators is grounded on the statistical model of safety transportation by railway and statistical substantiation of the type of casual events stream. This allows to select a specific model that describes the state of safety traffic by obtaining quantitative estimation of risk indicators.

It should be noted that operational environmental damage includes losses from the economic activity  $L_{ea}$  and payments for pollution of the environment.

Since the railway is a complex multifactorial system that contains both long-distance linear objects (routes for dangerous goods transportation) and local objects with significant potential risk (oil stores, petroleum terminals, fuel-and-bulk discharge refueling units), it is necessary to analyze the peculiarities of the criteria application for

comparing risks in various options for reducing the risk of the most dangerous situation, when dealing with oil products, and the expected loss of social components and infrastructure.



**Fig. 3.** Block diagram of the principle of risk management.

In the general case, for the analysis and quantification of risks, there are different methods, among which the most widely used are [3, 4, 5]: statistical method – Monte-Carlo method; analytical method; decision tree method and probabilistic approach, etc..

Each of the existing methods has its advantages and disadvantages and is used in particular situations; there is no universal method applicable to all cases. Under these conditions, to provide an objective choice of the most efficient methods of risk assessment 3 methods of parallel quantitative analysis were applied on the basis of screen-testing (figure 1) carried out by the authors.

Since each method is not without flaws, it is advisable to use several different methods in practice. The authors used the method of expert evaluation and the method of sensitivity analysis (analysis of the receptive status of objects). The results obtained by different methods vary, but the study of differences between them has revealed the factors contained in some methods and are absent in others, which affect the accuracy of evaluation and the reliability of results.

**Table 1.** Comparative characteristics of quantitative risk assessment methods

Characteristics	Methods of quantitative risk assessment						
	Statistical	Analytical	Tree of decision making	Expert evaluation	Normative	Sensitivity analysis	Analogues
Conditions of use	Known data of past periods of economic activity	Availability of detailed information about the project or activities	Known risk facts and the effects of their impact	Lack of information	Known key performance financial indicators	Availability of detailed information about the project or types of activity	Presence of analogues and the immutability of conditions of economic activity performance
Assessment	Absolute	Relative	Absolute	Relative	Relative	Relative	Absolute
Accuracy of evaluation	Not high	Medium	High	Not high	Not high	Medium	Not high
Expenses	Medium	Minor	Considerable	Considerable	Minor	Minor	Medium
Accounting of each of the risk factors impact	Minor	Impossible to determine	Highest	Practically impossible to determine	Impossible to determine	Practically impossible to determine	Minor

Based on the existing statistical data on main railway network operation in Ukraine, author's own research and expert assessments, the causes of failures were identified (delays, accidents and technological losses) and the likelihood of failure in different scenarios was identified (Table 2) [6, 7].

Analyzing the results of determining the likelihood of emission according to these scenarios, we see that the greatest danger of occurrence of railway traffic accidents (hereinafter – RTA) and technological losses of petroleum products is observed under violation of operation rules on the railways (Table 2).

Reducing risks that is the probability of these emissions' occurrence should be based on increased control over the timely (terms in accordance with the requirements of regulatory documents) repair works, control over the state of rolling stock, track and equipment, as well as improving the quality of training and knowledge testing of service personnel (operators).

**Table 2.** Risks of oil product emissions on railway transport under different scenarios.

No	Scenario (cause of emission)	Probability of emission, in shares	Probability of emission, in % of general quantity
1.	Operation rules violation	0,4701	47,01
2.	Wear	0,3213	32,13
3.	Defective construction and mounting works	0,1724	17,24
4.	Natural factors	0,0305	3,05
5.	Corrosion, external interference	0,0095	0,95

For the purpose of constant monitoring the authors have developed a new methodological approach according to which risk factors of both linear and local railway objects include receptive status and complex natural and technology-induced status of the geographical area of the object [6].

To create a database for electronic maps of receptive status and complex natural and technology-induced risks along the main routes of movement of trains with oil products the authors suggest a methodology of intensity recalculation of nature hazards. The analysis of natural and anthropogenic risks takes into account the degree of loading of railway lines (cargo tension).

Estimation of emergency situations probability at main railways, as well as the magnitude of damage to the components of the environment, allowed to calculate the ecological risk of accidents.

Taking into account the relatively small time to choose the rational solution and a large amount of related information (location of the source of an emergency situation at the station, rolling stock on adjacent tracks, adjacent production facilities and housing development, their population and fire characteristics, tactical and technical data of fire trains, ways of evacuation, etc.), it is expedient to automate the process of information collection and processing.

As the risk indicators are not similar for different main line sections the authors suggest using the total risk for the present moment which can be presented as a total of risks for railway sections with an equal probability of accidents and damage amount. The characteristic objects of negative impact during emergency emissions on railways are soils and underground and surface water bodies. Therefore the amount of ecological risk of a particular railway main line section was defined by the formula:

$$Rz_l = P_{abap} \cdot \frac{(\sum_{i=1}^n z_{zem_i} \cdot l_{zem_i} + \sum_{j=1}^k z_{eod_j} \cdot l_{eod_j})}{l_{maz}} \quad (1)$$

where:  $P_{abap}$  is the probability of an accident;  $l$  is the length of a section;  $z_{zem_i}$  is the ecological damage caused by pollution of the land by oil products of the  $i$ -th ecological vulnerability;  $l_{zem_i}$  is the length of the section of the main railway passing on the territory of the land of the  $i$ -th receptive status (environmental vulnerability);  $z_{eod_j}$  is the ecological damage caused by pollution (by oil products) of  $j$  water basin;  $l_{eod_j}$  is the length of the main railway section crossing or passing along the  $j$ -th water basin.

The risk assessment of transportation of oil products along the specified routes of high intensity was carried out according to the formula:

$$R_{3M} = R_m + R_{np} \quad (2)$$

where:  $R_m$  are anthropogenic risks;  $R_{np}$  are natural risks.

In this case technology-induced risks were defined as follows:

$$R_m = R_{HC} + R_{KM} + R_{AM} \quad (3)$$

where:  $R_{HC}$  is the risk of damage from accidents due to non-normative state of infrastructure elements;  $R_{KM}$  is the risk of damage due to the failure of communication networks and product lines with possible formation of striking effect;  $R_{AM}$  is the risk of the damage associated with the presence of highway crossings with possible traffic rules violation.

Risk of the damage associated with failure of communication networks and product lines with possible formation of a striking effect:

$$R_{KM} = \sum_j r_{KM} \cdot p_N \cdot \Omega_{3K}(\kappa) \quad (4)$$

where:  $r_{KM}$  is the risk of an accident in communication networks and at product lines;  $p_N$  is the probability of a train with petroleum products movement in the zone of detonation or outbreak of products that have flown out of the product pipeline;  $\Omega_{3K}(\kappa)$  is the distribution function of the loss associated with accidents in communication

networks and at product lines at railway bed crossing points, which is determined by the volume of oil product that has leaked and/or burst into fire in the area of an accident.

Risk of the loss associated with passing of highway crossings:

$$R_{AM} = \sum_j P_{AM} \cdot \Omega_{3M}(n) \quad (5)$$

where:  $p_{am}$  is the probability of an accident at the crossing with participation of a train with oil products;  $\Omega_{3M}(n)$  is the distribution function of the loss during RTA at the crossing.

In course of processing the obtained results the prediction of development dynamics of a dangerous (emergency) situation will be of unquestionable interest.

The main component of risks within large railway stations is the risk of social damage (up to 80%), which can be lowered by means of the use of bypass ways around densely populated areas.

Thus for the purpose of constant monitoring and possible risk management on railways in general the authors suggest a methodology of identification and assessment of risks arising during the transportation, storage and usage of oil products on railway on the basis of a comprehensive systemic evaluation and taking into account the receptive status of objects and their resistance to negative factors.

According to the suggested methodology the risk assessment is carried out on the basis of three indicators - risk frequency or probability; risk significance and dimension according to the receptive status of the object. To ensure their comparability and to make the qualitative assessment easier a ball scale is offered. (Tables 3; 4) [6, 7].

**Table 3.** Frequency or probability of dangerous products emergency emissions.

Point	Meaning	Frequency or probability
1	Very seldom	Once per 7 years and more rarely (probability up to 5%)
2	Seldom	Once per 5 years (or probability 25%)
3	From time to time	Once per 3 years (or probability 40%)
4	Frequently	Once per 1 year (or probability 80%)
5	Very frequently	Once per half a year and more frequently (probability > 95%)

The map-matrix of risks allows to assess the relative significance (ponderability, severity) of each risk (as compared to other risks), and to determine the objects of risk exposure, which are critical and require the development of measures for their management.

Construction of a risk map allows:

- 1) determine the potential for risks retention within the limits that can be applied to all railway operations;
- 2) to develop a list of critical risks for the railways and ensure appropriate processes for managing them;
- 3) determine the priority of risks and develop the distribution of financial resources.

The risk map is divided into several areas, highlighted in different colors.

- 1) Green Zone – risks with low probability of occurrence and (or) no significant impact on the biosphere (safe operation zone).
- 2) Blue zone – risks that have an average probability of occurrence or average potential impact (zone of relative tolerance).
- 3) Purple zone – risks with a high probability of occurrence or average potential impact (zone of environmental alertness).
- 4) Red zone – risks that are critical for a railway object or due to the high probability of occurrence or due to serious damage potential that may affect the financial viability of the railway (critical area).

Risk identification numbers are plotted on the map (regarding the registry) in accordance with frequency (probability) of risk occurrence and its degree.

Developed risk map is a graphic representation of an object's proximity to critical risks and should be a mandatory addition to the report.

**Table 4.** Frequency or probability of dangerous products emergency emissions.

Points	Degree of impact	Receptive status of an object $\sum_{i=1}^n RSt_i$ , points	Potential damage of the risk occurrence
1	Minor	< 8	Absence of any consequences in case of risk occurrence
2	Low	9-16	Consequences of risk occurrence are not significant
3	Medium	17-24	Consequences of risk occurrence are significant, but can be completely removed
4	Considerable	25-32	Consequences of risk occurrence are very significant, but can be corrected to a certain degree
5	Critical	> 33	In the case of risk occurrence, the railway will almost be unable to recover from consequences

Relative magnitude (significance) of risk is determined by the matrix map.

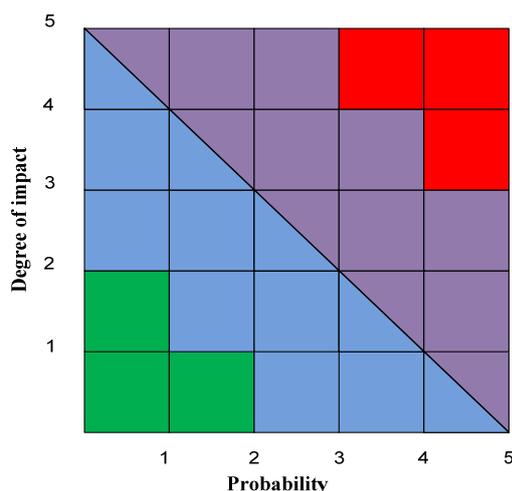
The priority of risks is determined according to the position of each of the risks on the risk map (Figure 4):

Group 1 – catastrophic risks – red area of the risk map – risks with the highest priority;

Group 2 – average risks – violet area on the risk map – risks of the second priority;

Group 3 – low risks – green area on the risk map – risks within the company's ability to maintain monitoring and control.

Inside each of the groups, the priority of risks is determined on the basis of the point of risk significance.



**Fig. 4.** Map-matrix for determining the importance (significance) of risks [2].

Each of the risks included in Priorities 1 and 2 is assessed on the basis of the following factors:

- 1) analysis of the causes of risks occurrence (scenarios of losses);
- 2) analysis of the potential impact of risks on the financial indicators of the Society – inherent risks (without taking into account risk management methods) and residual risks (residual risk after application of risk management methods);
- 3) analysis of the correlation of risks with other risks (repayment of risk negative effect in one unit with positive one in the other unit – the principle of compensation, or increase of negative effect in connection with occurrence of other risks – the principle of domino).

Thus, the methodology is a simple, efficient and affordable example of identification, assessment and further risk management capabilities on the railways. In this case, the final formulation of a permissible risk becomes necessary.

#### 4 Models of management by ecological and information systems

For efficient management of transportation process, not only reliable data and their timely receipt, but also the possibility of their operative interpretation, which lead to the use of the geoinformation approach, are needed. It combines graphical visualization tools with spatial analysis and data sharing tools that facilitate the efficient organization and data management [6, 8, 9, 10].

From the analysis of environment condition in the areas of potential risk of oil and oil product pollution conducted by the authors, it appears that the variety of factors determining integral sensitivity of nature objects in the main line area stipulates the necessity of systemic approach to the problem of prevention and elimination of emergency situations connected with accidental oil spills. In connection with this an important task was to develop methods of design, calculation and comprehensive assessment of sensitivity of a chosen main line section which required the usage of modern

geoinformational technologies. In accordance with this the integral sensitivity of the section of Pyatykhatky locomotive changing point area was considered as a total of sensitivity indices of biota existing here in a certain stage of life cycle. For the objects of environmental management the authors have accepted a relative indexation, that's why during the assessment of integral sensitivity only the presence of some kind of manufacturing is taken into account.

The geoinformation approach and GIS mapping allowed to develop the understanding of the information flow regulation system, ranging from cartographic support to the decision-making system, resulting in effective participation in regulatory mechanisms.

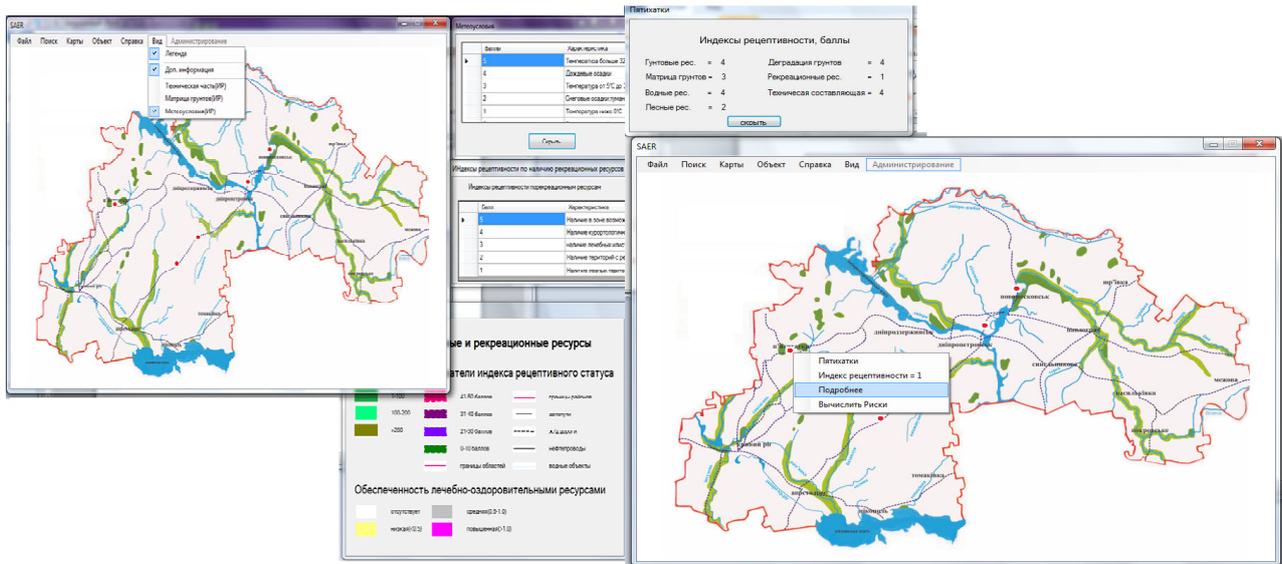
As the basis of the ecological security system, topographic maps and plans specially digitized have been used. The difference between cartographic projections raises the task of harmonizing the underlying basis for adequate perception of information. The geoinformation approach provides the opportunity to optimize the program of environmental monitoring in the area of transportation, storage and use of petroleum products, supporting various analytical operations, providing spatial data management and information transmission services, as well as their cartographic representation at the decision-making stage [8].

Integration of databases of different structures allows using the system for solving various application problems. This system is open, therefore, depending on the emerging tasks, it is possible to construct new modules, their algorithmic and software, and thus, their visualization.

For systematized analysis, as well as evaluation and ranking of objects of railway transport according to their potential environmental impact, the authors recommend using maps of receptive status of objects – sensitivity and stability of environmental objects to anthropogenic loading.

Receptive status maps are part of the scientific and methodological support of the ecological safety system, which allow developing a response strategy for elimination of RTA (accidents). This is one of the main resources that management and decision-making bodies need to take when making decisions, assessing the consequences of accidents (emissions), as well as calculating necessary response facilities and their locations, based on typical conditions for the given area.

Receptive status maps are not just a set of electronic maps with the ability to simulate different map configurations, but also provide access to the database of objects marked on this map. Availability of attributive information of cartographic objects and communication with databases provides qualitatively new possibilities for analysis of available information. The considerable amount of data contained in receptive status maps, the possibility of optimal organization, their processing and operation, determined the need for creating information system that allows operational access to necessary data for decision making in the face of pollution threat to natural ecosystems. The basic scheme of environmental safety management on the railways and mapping of receptive status is presented in Figure 5.



**Fig. 5.** Dialog boxes of the software package.

In addition, the sensitivity maps make it possible to identify quickly priority areas at emission elimination, to simulate and predict the process associated with oil emissions, as well as to assess the damage caused by the discharge of petroleum products.

The information-analytical block of the decision support system provides:

- accumulation and provision of information that is necessary for decision-making in emergencies;
- determination of risks of environmentally valuable areas contamination and the choice of the best methods for pollution elimination;
- determination of environmentally vulnerable to oil pollution objects of the environment;
- calculation of losses incurred by the emission;
- representation of the most valuable objects located in the zones of main lines operation;
- the ability to integrate information for spatial operations realization.

The efficiency of various blocks of the information-analytical system increases due to the use of distributed databases and the creation of complex models. It includes five key components: hardware, software, data, methods and executors.

Thus, the developed map data bank that is connected to any spatially distributed data of operation zone of railway lines and units has become the basis of the whole system.

The functioning of a suggested software package (figure 5) is performed with the help of database management which contain specially designed blocks and spreadsheets.

The informational system makes it possible also to optimize and reflect in cartographic form the routes of advances of forces and funds into the area of spill, sites of storage and utilization as well as to create alert systems and communications for localization and elimination of accidental oil spill consequences (fig. 4).

The procedure of determination of receptive status of object [11]. The maps of sensitivity of main line areas to

oil pollution are presented as a graphic model of ecological situation in the area of accidental spill risks. They show the distribution of environmental objects and provide a possibility to establish priorities while protecting the most vulnerable components in course of oil spill elimination.

The maps of sensitivity contain not only the information about the environmental state of the area of potential pollution and make it possible to measure the vulnerability of biota to oil influence but also give a possibility to make a prompt prognosis of the process connected with accidental spills and estimate the economic harm inflicted.

The solution of the task to choose the best technology of a railway section cleaning is presented as a sequence of operations that give a possibility to make the algorithm of the procedure. Every section presented on the map was referred to a certain index in order that the user has a possibility to choose an adequate technology. After filling in the form proposed by the module that includes data about the amount and type of accidental oil product emission the user consequently gets the justification of the choice of technology which is the most appropriate in these circumstances. Such job was done for a section of Prydniprovsk railway in the area of Pyatykhatky locomotive changing point.

The developed maps of sensitivity made it possible to identify the sites of potential pollution of the chosen area. This area comprises sites having different sensitivity to oil pollution.

The methodology of automated selection of technology of cleaning sections of railway main lines during elimination of accidental spills of oil and oil products developed by the authors is based on the defining the degree of ecological sensitivity of nature objects in the railway area and options of reacting that provide the least environmental impact. Thus it helps to optimize the ecological and economic result of elimination of accident consequences.

A particular complex of methods and technologies of elimination of ecological consequences of oil emissions is chosen with the help of specific matrices developed by the authors according to clearly differentiated scenarios of emission development (e.g. Scenario 1. A leakage from a tank or a container for storing heavy oil products onto the surface of the ground without the threat of geofiltration; Scenario 2. A leakage from a tank or a container for storing light oil products onto the surface of the ground with further geofiltration; etc.)

## Conclusions

1. The principal scheme of the ecological situation management system on railway transport is proposed, which allows to carry out systematic analysis of heterogeneous data: monitoring of geographical, technological and production tasks, and provides the possibility of full, reliable and timely decision-making management as for the technical system of railway transport.
  2. On the basis of analysis of statistic data about emergency situations arising during transportation of oil products, a hierarchical structure of malfunctions of socio-technical system of railway transport is developed.
  3. A methodology of ecological and economic assessment of emergency risk during transportation, storage and usage of oil products on railway transport is developed.
  4. With the usage of the main methods of emergency risk management during transportation of oil products along railways the authors suggested a complex of measures aimed at the optimization of the process of situation assessment and making adequate decisions on reducing the size of environmental damage.
  5. A conceptual device for identifying and determining environmental risks is proposed.
- The proposed scientific and methodical device gives opportunities for operative management of ecological and economic risks on the railway, in particular, when dealing with oil products, by continuous monitoring, using GIS-technologies, and system analysis on the basis of the special software program that is specifically developed and functioning.

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