Information and analytical support for the industrial and ecological safety management of Arctic communications

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Abstract. The article is devoted to information technologies for ensuring the technogenic-ecological safety of the Arctic communications development. Creation of information technologies requires taking into account of global, federal, regional features and developing of modern methods and approaches to hazards and risks modeling and assessing. An assembly technology for weakly structured problem-oriented information in the field of Arctic regions safety management has been developed. A feature of the technology is the use of modifiable structures - patterns, which ensures the automation of the project domain conceptual model generation. An information and analytical system to support emergency control planning at the level of potentially hazardous industrial objects and complexes has been developed. By integrating the functions of accessing to the normative and methodical foundation, of generating the typical planning documents, of risk estimating and of maintaining the safety management archive the system ensures the fast generation of the necessary plans and documents for the prevention and elimination of typical industrial and natural accidents. The system was tested during the designing of planning documents for a number of potentially dangerous objects and complexes of the Murmansk region and the applied problems solving in field of Northern Sea Route ecological safety. The obtained results provide a time reduction and labor saving for the design and coordination of managerial decisions in the socio-economic and natural-technogenic regional crisis situations. Developments can also be used to new systems synthesize for distributed safety management of complex socio-economic objects, as well as to improve the operability and accuracy of existing systems for safety support of critically important objects and infrastructures.

1. Introduction

The acts [1-3] are the basic strategic documents that determine the policy of the Russian Federation (RF) and regulate the issues of national safety in the Arctic zone (AZ). The specificity of AZ RF development is, on the one hand, that the regional safety level essentially depends on global threats, on the other hand, that possible crises and emergencies caused by the region features can lead to destabilization of higher-level systems - federal, international, world [4]. Logistics and transport issues are of high importance for the Arctic regions, and they must be resolved with acceptable level of industrial and ecological safety. The development of the Northern Sea Route is one of the key, backbone factors that determined the development priorities of the AZ RF. Extreme climatic conditions, focal (cluster) nature of the territories development, low population density, remoteness from major industrial centers, high resource intensity, dependence on other Russia regions and foreign partners, ecological systems vulnerability are the safety-relevant features of AZ RF [5]. Note the poor
knowledge of the problem of Russian Arctic industrial and ecological safety, combined with the increasing dynamics of technogenic and natural changes. The Murmansk region, a unique subject of the Russian Federation, was chosen as a base for research and testing from the point of view of its geopolitical and geo-economic position, its role in ensuring the country’s defense, and its natural resources. A number of major projects focused on the Arctic and Northern Sea Route development are being implemented at the region.

The RF Arctic communications technogenic-ecological safety is the object of research in the work. The models, methods, information and analytical support technologies for the risk-sustainable development of RF Arctic regions industrial-natural complexes and communications are the subject of research. The working out of information technologies to ensure technogenic and ecological safety in the AZ RF development is the purpose of the research. Use of mathematical and computer simulation tools is one of the current approaches to solving the problems of technogenic and natural disasters risk reducing. The working out of information technologies requires to take into account the global, federal, regional features and to develop the modern methods and approaches to hazards and risks modeling and assessing.

2. Existing approaches, methods and safety support systems
To date, various concepts and approaches to risk management have been developed and applied: probabilistic and statistical methods, logical-probabilistic modeling, fuzzy set method, nonlinear dynamics, multi-agent technologies, network centric approach etc. The construction of federal and regional automated systems, situational, cognitive and other emergency (ES) management centers is actual and discussed in many publications. Such information and control systems and services are created, including within the framework of the unified state system for the prevention and elimination of emergencies. At present, the National Crisis Management Centre (NCMC) of the Russian Ministry for ES (RMES), NCMC of the regional centers and of the directorates of the RMES can exchange operational and statistical data about emergencies, which suggests the beginning of the formation of a uniform information area for safety management. The possibility of data exchange with the duty-dispatch services and situational centers of ministries, departments and executive authorities is also provided. At the municipal and object levels the formation of automated services and emergencies control centers is at an early stage.

In modern studies the methodological risk decision-making scheme is divided into two large blocks: assessment and/or risk analysis and risk management. Risk analysis includes hazard identification and quantitative risk assessment. Risk management involves the development of alternatives, the assessment of options, the selection of methods of influence to the control object and the implementation of selected impacts. One of the actual international trends is the transition from the concept of reactive (Safety-I) to the concept of proactive (Safety-II) risk management [6]. The first approach involves a responsive strategy, focusing on problems, the desire to minimize possible damage. The second approach implements a proactive strategy, a focus on normal functioning, the desire to maximize the number of "successes" and to solve tasks. The solutions developed in this work are associated with supporting of risk-sustained, active development management and are in line with the concept of Safety-II.

Note the foreign counterparts dedicated to the particular aspects of safety and risk inherent at the Arctic zone: oil and gas production, climate change, ecology, health care. As an example, one can cite article [7] on the assessment of the risk to the health of the indigenous population of the northern territories as a result of the consumption of traditional vegetable food exposed to chemical emissions. Another example is the work [8] performed in Sweden and established a correlation between the readiness to become parents and the perception of the climate change risk.

In a number of domestic investigations, the idea of creating a network of cognitive centers (branch, regional, corporate) is being developed, which is the development of the idea of situational centers [9]. The possibilities of brainstorming, attracting of remote experts are complemented by a system of mathematical models of analysis and forecast, by knowledge bases. Such centers also have the task of
rare and large emergencies preventing (strategic risk management). It also considered a set of problems to increase the efficiency of management of the socio-economic development of the Russian Federation Arctic sector. The methods of structural-dynamic scenario analysis are used as the scientific and methodological basis for information support of policy in the Arctic [10].

The tasks of carrying out of active information campaigns are considered taking into account the external destructive information effects of geopolitical opponents. For their solution the methods of scenario research of information confrontation simulation models are used. These methods are based on the use of the mathematical apparatus of weighted and functional sign digraphs (multigraphs).

In [9, 10] the results of modeling the development of a number of Russian regions are also presented. The methodology of cognitive modeling is a set of methods and technologies that are combined by cognitive approach to the complex systems analysis. On the created cognitive maps the model experiments were carried out, which made it possible to identify dynamic trends of the main spheres of vital activity, to identify possible scenarios and determine the conditions for sustainable development.

One of the research directions is to ensure the safety of critically important objects (CIO) of the transport and information infrastructures [11-13]. The «Risk-Manager» automated system (AS) was created and put into operation, allowing to solve a tasks complex related to the construction of CIO protection systems and to monitor the safety state of these objects. The AS allows to create the protection profiles, to organize the monitoring and recording of compliance with safety requirements. It also provides the safety compliance reporting. Software and hardware complexes of the AS can be installed at workplaces of officials responsible for the safety of the CIO.

Important safety features of the AZ RF are noted in the introduction. Add to this the underdevelopment of the information and telecommunication infrastructures, the relative autonomy of objects and territories (complexes, clusters), which does not allow to directly transfer solutions developed for the “mainland”. Therefore, it requires modification, development of existing methods and approaches, as well as the development and implementation of new information technologies to support the safe development management of the AZ RF. This necessitates the creation of additional means of forming a preliminary conceptual domain model for many tasks of strategic and operational management.

3. Tools for constructing a conceptual model of safety management

The decision-making information incompleteness and inaccuracy, the lack of a uniform information field, both at the stage of forecasting, planning, and during localization and liquidation of emergencies are the one of the actual problems in safety management of the RF Arctic regions. In particular, this explains the sometimes showing information disconnection and discordance in the functioning of heterogeneous control centers and authorities, as well as the irrationality of the forces and means use in the accidents and emergencies control.

To reduce the acuity of this problem an technology of aggregation for weakly structured problem-oriented information has been developed. The general algorithm of the technology is shown in Figure 1.
At the initial stage the current management objectives and problems (research directions, uses) are formulated by choosing from the appropriate pre-developed list (tree) of opportunities. Depending on the chosen directions, the generation is also carried out in advance of also pre-developed possible patterns - structures. The choice of the desired pattern can be carried out by keywords, from the general list or by other means. Choosing and filling out patterns with specific information, the user gradually formalizes and concretizes the actual domain conceptual model. At the same time it clarifies exactly what data and in what form is lacking for reasoned decision making. If necessary a request for additional data is formed or various possible data options are entered. If there is enough information for decision making, the selection of the calculated models from the corresponding list is performed. Here the fact of incomplete list of calculation models can also be detected, which will require additional efforts to replenish it. Further, if necessary, on the basis of the passed stages, an automated output document is produced, also with the involvement of a typical forms list.

The technology aims to create (due to unification) a uniform information field for decision-making as well as to coordinate of organizational and functional management structures for typical regional emergencies and crisis situations. The design and implementation of regional safety management systems is the applied purpose of the technology. Thus, the technology is based on typical modifiable structures — patterns (forms) that contribute to the synthesis of a domain conceptual model. Such pre-prepared forms include: a tree of objectives and problems, typical structures of hazardous processes and objects, schemes of typical processes and objects safety analysis, describing structures of possible accidents and emergencies, stages of emergency control, decision-making tables, area maps, infrastructure schemes, data on the location and equipment of forces and means etc., as well as typical structures of the regional safety management bodies. The set of forms (patterns, structures) is modifiable and replenishable.

Thus, in dialogue with the user - expert and by using the pre-designed typical blocks and structures, a gradual increase of the safety management system functioning information model is carried out. The technology allows to build up the model which appropriate to awareness level and to identify the missing data for decision making.

For typical industrial-natural systems of the Arctic regions the technology provides analysis and risk assessment of heterogeneous emergencies as well as the synthesis of safety management structures and plans corresponding to these situations (Fig. 2).
As a prototype that implements the principles of the proposed technology the presented below information and analytical system is developed.

![Diagram](image)

Figure 2. Development of safety management plans

4. Information and analytical support system for emergency control planning in the Arctic zone of the Russian Federation

It is convenient to conduct a study of regional safety management systems functioning on the data of the associated documentation development. It reflects and concentrates the stages and problems of safety management. The analysis of this component for the level of potentially hazardous objects and complexes allows to conclude that the creation of documents for industrial and ecological risk assessing and reducing, planning for possible accidents warning, localizing and eliminating - passports and declarations, action plans etc. - is the main part of the works. We shall shortly call such documents by the general word “planning documents”. These documents are supervised by various ministries, are subject to approval by various departments, many must be expertised.

Issues of industrial and natural safety are regulated by the relevant normative and methodological base. In addition there are a lot of documents at the regional and local levels: registries, licenses, regulations, orders.

Analysis of the set of planning documents shows that they have similar blocks and / or sections. This partial duplication is observed even within a single document. The typical document includes three sections (blocks).

The reference information is the first and it contain the initial information on an object of this type. The second block is devoted to the assessment and calculation of hazards and risks. The third section covers the issues of preventing and eliminating possible accidents and emergencies. The filling of sections is governed by numerous documents. Despite the diversity of regulatory documents,
methodological materials, especially those that take into account the specifics of the Arctic regions, are clearly not enough.

The idea of unification and creation of an information and analysis system or modeling environment is naturally arises. The system is created in order to provide decision support in the field of prevention and elimination of technogenic and ecological emergencies. Using such a system it will be possible to solve the problems of strategic planning and operational management: designing a regional safety management system, emergencies preventing, optimizing the actions of emergency control forces and facilities and other.

The system includes the following three blocks of models.

The model of a hazardous object or a regional industrial-natural complex, which includes models of organizational and functional structures, infrastructure, territory (water area).

The model of the safety management system functioning, which includes structural models as well as models of the functioning of emergency control forces and facilities.

Hazard assessment and risk management models aimed to solve the problems of ES prediction and prevention as well as operational management.

Each of the blocks, in turn, is subdivided into lower level blocks and models.

The analysis and generalization of the works executed on the research of hazardous industrial and ecological objects and complexes of the Murmansk region allowed to formulate a project of an information and analytical system to support planning for industrial and natural accidents and emergency control.

By integrating the functions necessary for the prevention and elimination of technogenic and ecological accidents and emergencies (access to the normative and methodological base, generating the form and content of typical planning documents, performing risk assessment calculations, maintaining an archive of safety management data), the system provides automated formation of operational and informed decisions for typical objects of the Arctic and of the continental shelf.

The general algorithm of the system functioning (on the example of creating a planning document) is shown in Fig. 3

![Algorithm for creating a planning document](image)

At present, a prototype of an information-analytical system that implements the above algorithm has been developed.

The system is recommended for use in industrial safety services at various levels, in scientific and design organizations, as well as in the units of the RMES and Rostechnadzor - towards the creation
and implementation of modern information and telecommunication technologies that provide prediction and prevention of natural and technogenic emergencies, elimination of its consequences, effective safety control of the economic and other activities in the Arctic. To implement the system it is necessary to adapt the software for a specific enterprise or regional industrial complex. Depending on the information readiness degree of the object this setting can be carried out from one month to six months. An increase of the safety level of development of the typical potentially dangerous and critically important objects of the RF Arctic regions, an increase in the efficiency and reasonableness of decisions to manage their industrial and ecological safety are the possible implementation effects.

The work was done in line with the priority areas of the RF Strategy of the Scientific and Technological Development, which ensure: transition to advanced digital production technologies,countering of technological and ecological threats, territory connectivity of the AZRF through the creation of information and telecommunication systems.

The system was tested during the development of planning documents for a number of potentially dangerous objects and complexes of the Murmansk region. The system components have been certified at the state registration of programs. At the recently concluded "International Competition of Scientific, Technical and Innovative Working-Outs Aimed to the Development of the Arctic and the Continental Shelf 2018" the work was awarded by the First Prize Laureate Diploma.

5. Conclusion
The problem of information technologies working-out for ensure the technogenic-ecological safety of the AZ RF developing is considered. A brief review of existing regional safety management methods and systems has been carried out.

An assembly technology for weakly structured problem-oriented information in the field of RF Arctic regions safety management has been developed. A feature of the technology is the use of modifiable structures - patterns, which ensures the automation of the project domain conceptual model generation.

An information and analytical system to support emergency control planning at the level of potentially hazardous industrial objects and complexes has been developed. By integrating the functions of accessing to the normative and methodical foundation, of generating the typical planning documents, of risk estimating and of maintaining the safety management archive the system ensures the fast generation of the necessary plans and documents for the prevention and elimination of typical industrial and natural accidents. The system was tested during the designing of planning documents for a number of potentially dangerous objects and complexes of the Murmansk region.

The completed works were tested in the implementation of the «Strategy of the Russian Federation Arctic Zone Development and National Safety Support for the period up to 2020» in the Murmansk Region and for the applied problems solving in the field of information support of the Northern Sea Route ecological safety. The obtained results provide a time reduction and a labor saving for the design and coordination of managerial decisions in the socio-economic and natural-technogenic regional crisis situations. Developments can also be used to new systems synthesize for distributed safety management of complex socio-economic objects, as well as to improve the operability and accuracy of existing systems for safety support of critically important objects and infrastructures. This work was supported by the Russian Foundation for Basic Research (project No. 18-07-00167-a).

The conducted researches correspond to a number of priority areas of the Strategy for the Scientific and Technological Development of the Russian Federation. Promising areas for further researches are related with the creation and development of models and software tools that provide automated working-out of planning documents for safety management of critically important objects and infrastructures of the polar regions as well as with further unifying and optimizing management information support.

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