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Information technologies for industrial-ecological safety management support of regional mining complex development (on the example of "Apatit" mineral resource industry Public Corporation)

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Abstract. The paper represents research and work out results and contributions in the field of information technologies design for industrial-ecological safety management support of regional mining complex development (on the example of "Apatit" mineral resource industry Public Corporation). The computer technologies and software tooling system architecture for safety management information support of regional industrial and environmental complexes (systems) have been developed. An integrated unified management approach for ecological risks evaluation and mining industry heterogenous threats analysis of regional safe development has been proposed. The paper considers practical implementation and embedding of received research results.

Аннотация. В статье представлены теоретические и практические результаты научных исследований в области создания и развития информационных технологий и компьютерного моделирования для решения задач управления промышленно-экологической безопасностью развития регионального горнопромышленного комплекса (на примере ОАО "Апатит"). Разработан комплекс информационных технологий и программных инструментальных средств информационной поддержки управления безопасностью развития региональных промышленно-природных комплексов. Предложен единый методический подход к комплексной оценке экологических рисков и анализу разнородных опасностей антропогенного воздействия горнодобывающей промышленности на региональные подсистемы для целенаправленного управления промышленно-экологической безопасностью региона. Приводятся сведения о практической реализации и внедрении полученных результатов.

Key words: information technologies, mineral resource industry, regional mining complex, industrial-ecological safety, management, information and analytical support, simulation, system dynamics, agent-based systems

Ключевые слова: информационные технологии, горнодобывающая промышленность, региональный горнопромышленный комплекс, промышленно-экологическая безопасность, управление, информационно-аналитическая поддержка, имитационное моделирование, системная динамика, мультиагентные технологии

1. Introduction

1.1. Problem statement: a brief overview and relevance foundation

Currently, national and regional economic development is tightly determined by the global patterns, which on the one hand, contribute to economic growth and thus provide the increasing demands of a rising number of population, and on the other hand, lead to a rising uncertainty and the volatility of development. Emerging perturbations are hardly to be forecasted and being the destabilizing factor, greatly complicates the socio-economic management.

These circumstances in the context of globalization require a comprehensive solution of the economic, social, scientific, technical and environmental challenges and give special value to sustainable socio-economic development pattern.

The requirement to shift the regional socio-economic system to the sustainable development pattern, which enabled to satisfy the increasing demands of today's and future generations through the harmonization of economic, social and environmental subsystems, speaks development safety as the protection against internal and external threats.

The theoretical agenda of the sustainable development in socio-economic systems shows the following disadvantages:

1) there are no clear definition of basic related terms "sustainability" and "safety" of the socio-economic system;
2) there are no formally defined sustainability and safety criteria;

3) there is no unified sustainability and safety estimated methodology;
4) there is no revealed specifics of regional sustainable socio-economic systems development;
5) there is no main indicators coordinated system for sustainable development.

Present geopolitical and socio-economic situation of the Russian Federation stipulates a number of external and internal safety challenges in different sectors and levels of society. Currently safety is considered as the major factor of sustainable development at the present and follow-up stages of public relations progress. The special significance shows the problem in Arctic regions, which are becoming the main foundation for further country development.

The Russian Arctic zone is characterizes with extreme natural-climatic conditions, point economic and industrial development, low population density, remoteness from the main industrial centres, high dependent on resources and both on other Russian and foreign partners, low environmental sustainability.

Specifics of the regional socio-economic system development safety (in particular, in Arctic conditions) is that, on the one hand, the safety level of the region is tightly depended on global threats, on the other hand, potential crises and emergencies arising from the regional peculiarities could lead to higher-level systems destabilization – Federal, international, world. Key to the effective functioning of the regional safety system are: firstly, the sustainable development of all the spheres – social, economic, scientific, technical, industrial and environmental; secondly, the stability of the system of regional governance and control in these areas; thirdly, regular monitoring and analysis of existing and potential safety threats; in yet others, the substantiation and conduct of preventive activities in the area of regional safety.

The scientific problem is to develop the scientifically grounded bases issues for safety management of regional socio-economic development: fundamental and applied problem definition and it's solving to provide sustainable development of the region as a complex socio-economic system in a rapidly changing internal and external environment.

The subject is a scope of theoretical, methodological and procedural issues related to information and analytical support for regional safety management.

The study proposes to consider safety of socio-economic development of the Arctic regions (Murmansk region) as a complex dynamic open system, which is a set of interacting state, municipal, economic, scientific, educational and other structures.

The main research aim is to design, develop and study the cognitive models, methods, technologies, information and analytical support of regional development safety management to enhance sustainability of regional economic system and to create relevant frameworks to growth of intellectual, industrial, innovation and socio-economic potential of the region.

The research relevance and significance are determined by the growing importance of Arctic regions for national economy and defense, moreover, that there is intention to establish an Arctic research and safety centre in the Murmansk region. The RF Government has adopted the "Fundamentals of State policy of the Russian Federation in the Arctic until 2020 and beyond" (approved by the RF President on 18.09.2008) which provide the basis for such a center establishment.

The Murmansk region is a unique Arctic region in terms of its geopolitical and geo-economic situation, role in the defense of the country's and natural resources reserves. The Murmansk region is characterized by a highly educated population with above-average level of vocational training, advanced training system, significant scientific research potential, the core of which is the Kola Science Centre of the Russian Academy of Sciences closely cooperated with central academic and governmental research organizations. The city of Murmansk is the Russian main post in the Arctic.

The main safety types for the Murmansk region are technological, environmental and social. There are various potentially dangerous objects, processes and parameters in every of these types. Followed are some regional issues seemed to be actual for regional safety problem. Almost all the territory is located above the Arctic Circle in harsh climatic conditions. There is a large international maritime trade routes node in the region. The border area has military-strategic and economic importance. The region is overloaded with defense industry facilities. Prominent role is played by external relations with the Federal centre and with foreign partners. Relatively others the region is tightly dependent on external factors, such as global processes (the prices for apatite, nickel, aluminium, copper), provisioning (a large part of import foods), fuel supply, financial support, transport capacity. The region is characterized by some historically developed industrial branches: mineral-raw materials-mining complex, fishing base, military-industrial complex, energy) and enterprises forming a company towns.

1.2. Brief theoretical novelty explanation

Theoretical basis to create scientific-methodological and practical foundations of safety management in the Arctic region of the RF is the sustainable development conception with it is basic principle to achieve a balance of economic efficiency, social justice, environmental life demands and the needs of present and future generations. However, this principle cannot be used to formalize the global aim in studying and modeling of regional socio-economic systems because it is exclusively for world ecology-economic system that is essentially "closed".

Additionally, the sustainable development concept, based on the principle of "do no harm", could not be implemented in current circumstances because of safety risks and threats to development remain elusive; absolute safety is unachievable and minimally acceptable one is inefficient. It seems appropriate to use a well-known in theory an acceptable risk safety principle, i.e. risks which are possible and valid in terms of socio-economic and environmental issues of safety development, acceptable enough risks in order to obtain certain positive results for society. The acceptable risk rate is defined in accordance with standard of knowledge, state level of socio-economic development, public opinion and regional peculiarities. Foundation of regional development acceptable risk is independent scientific challenge.

The proposed strategic approach considers the Arctic region not only as important sources of raw materials for further development, but also as a unique megaregion, where a significant proportion of the GNP generates by the population in extreme conditions, exceeding most regions rates per capita and providing a strategic presence of Russia in the North and the Arctic. A new approach to Russian North development implies to overcome trends to use "casual workers" psychology focusing on inhabited North, to create comfortable conditions for permanent living, active safe development and system investments to human capital.

Theoretical novelty of our research work is to create a set of cognitive methods, tools, and technologies to design the open extensible information-and-analytical environment, to focus on regional safety socio-economic management, to provide facilities to implement the acceptable risk conception, to information support of relevant structures in the area of regional safety subsystems, to create step-by-step a comprehensive safety system to protect the territories, populations and critically important for national safety of the RF Arctic zone objects from threats of natural and man-made disasters.

The significance of the proposed studies is also the firstly developed scientifically-methodical foundations to integrate technologies of conceptual, system dynamic and multiagent modeling, detailing the modern concepts of a unified information management environment for problem-oriented activities. This would provide integrated modelling of complex social and economic systems and processes, as well as design of information technology for effective support of regional safety development.

Implementation of the proposed approach to integration of multi-agent technologies, system dynamic model of safety management technologies of regional industrial-and-natural complexes within information and analysis of safety management support environment will ensure the possibility of establishing regional development polimodel complexes of spatially-distributed complex systems. The complexes are the basis for design and study the regional development scenarios with simulating of complex dynamic processes and interactions between task-oriented activities shown as pro-active agents.

1.3. Proposed solution grounds

A comprehensive methodological framework to study and regional safety development management may be derived with combining various scientific concepts, information technologies and modeling tools, such as conceptual modeling, self-organization theory, multi-agent technology, control theory, System Dynamics, simulation, common systems theory, mathematical theory of safety and risks, analyses of safety, stability and optimization in nonlinear dynamical systems, control theory and complex dynamical systems under uncertainty and chaotic behavior system modeling, mathematical methods for complex heterogeneous systems, etc. However, the approach proposed to address scientific problem is formulated in the application of methods and tools for conceptual modeling, integration of multi-agent technologies and system-dynamic modeling to obtain qualitatively new solutions in the area of information and analytical support systems operation and management of the development of complex dynamic systems. Conceptual integration, system-dynamic and multi-agent models would allow effective management of socio-economic system as in stable and transition contexts.

It is proposed to use cognitive approach based on conceptual modeling technology to describe the structure and peculiarity of the safety challenges in regional development. The technology will provide integrated formal knowledge representation on the structure of subject area and will present tasks and executive environment of information-and-analytical support.

A great potential to apply to the task of regional safety development is provided by system dynamics method in terms of complex processes modeling in socioeconomic systems, characterized by complex, novel situations and lack of formalization.

Using the multi-agent systems technology will provide an adequate environment to information-and-analytical support management in region safety development, taking into account the distribution and structural complexity of formative subsystems. Intellectual pro-active agents may be selected to manage certain aspects of regional safety development and based on problem-solving coalition interactions of agents it's possible to provide effective operation of the self-organizing infrastructure of regional safety and its separate components, as well as maintaining an acceptable level of safety for the future development.

Development of information technology to regional industrial-and-natural systems safety management will allow to design a system of basic terms of the subject area, hierarchical relational structure of heterogeneous potential hazards, unified mathematical description of the regional development safety.

1.4. Practical significance of expected outcomes and possible areas of application

Development of scientific-methodical bases of study and safety development of the RF Arctic regions and practical implementation of information technologies aimed to support regional safety management will provide an open, extensible and versatile infrastructure safety management at the regional level. This infrastructure realizes effective instruments for analysis, forecasting and localization of internal and external hazards to regional safety development, as well as mechanisms of synergize regional institutional structures aimed to solve dome challenges of regional development safety.

Practical significance of proposed research is to develop theoretical and methodological bases and technologies of regional safety management aimed to sustainable regional development in a changing domestic and external environment for the short and long terms.

Main results are to be obtained in the course of research work and can be used to generate an integrated regional safety management system in the RF Arctic zone in frameworks of national RF safety strategy up to 2020 approved by the President's Decree May, 12, 2009 N 537 and governmental order "The fundamentals of the RF State policy in the Arctic for the period up to 2020 and beyond" (approved by the RF President 18.09.2008). Additionally, the findings and recommendations may be used in training, retraining and further training of State and municipal employees in the field of regional socio-economic development safety management in the Arctic zone.

2. Information technologies for management support of industrial-ecological safety of regional development

One of the important functions of the development regional management is the industrial ecological safety providing. Many regions formed developed industrial nature social complexes (enterprises forming one company towns) in decades that determine territorial safety level and represent independent competent research object. Such relatively isolated systems (mining complexes first of all) are important and typical for the North of Russia. They are the unique region "centers of crystallizing". Industry, infrastructure and people concentrate here. Preconditions of the dangerous situation causes are the high density of the objects, productions, energy and dangerous substances. So that large enterprises are the objects of security specialists' high attention.

"Apatit" public company has been chosen as an example of typical and relatively well-learned mining complex (MC). There are over 13 thousand people works on the enterprise. It occupies about 70×30 kilometers of the territory (Fig. 1). Enterprise was founded in 1929 and now it is the enterprise forming company towns Kirovsk and Apatity. "Apatit" public corporation is the world largest phosphorous-containing raw material producer. It is mining and treating raw materials. Modern state of the mining and treatment is characterized by the application of the advanced technologies with a high level of production process mechanization and automation.

Rational usage of information resources, modern information technologies particularly is one of the actual approaches to type complex safety problems. Institute for Informatics and Mathematical Modeling of Technological Processes of the Kola Science Center of RAS (IIMM KSC RAS) researches industrial ecological safety problems and risk management since its foundation in 1989. This article contains main directions and efforts since last years.

3. The common framework basics of the development safety formal description of the mining complex

3.1. Conceptual framework

Necessity of the conceptual framework building still refers to the lack of common adopted terminology in the "danger science". There are disputes about basic definitions of danger, safety and risk. That's why authors forced to present their interpretation of used terms every time. The current work is generally based on established and approved earlier hierarchical system of the basic conceptual frameworks (*Yakovlev*, 2001; 2004). There are current work approved interpretations below. We need to mention that these definitions were primarily directed at applied and constructive content that allows quantitative interpretation.

Danger is something's or someone's property to cause someone or something harm. Thereby danger is a qualitative definition. You need to specify the "source" and the "receiver" (object of danger influence, recipient, target) when you tell about danger. This definition has a definite meaning only this way.

Industrial nature (anthropogenic-ecological) dangers are dangers which sources and receivers are anthropogenic nature environment objects.

Emergency conditions (EC), accident, natural disaster are appearances and realizations of anthropogenic-ecological dangers.

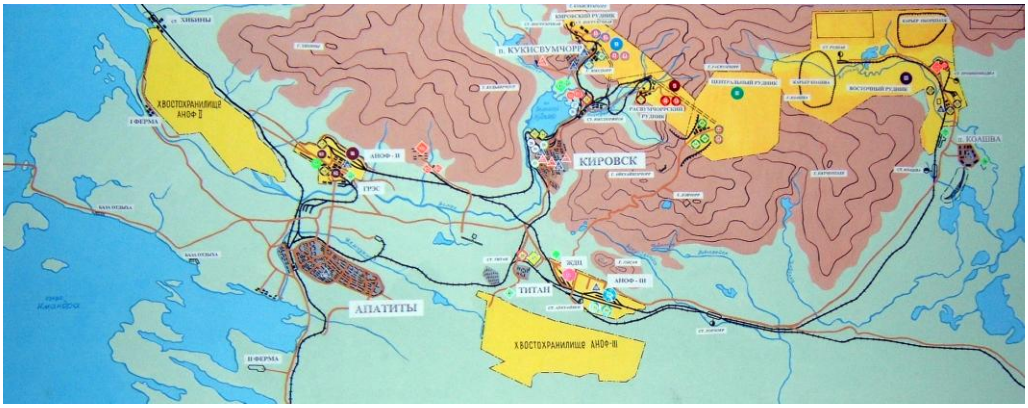

Fig. 1. Main industrials of "Apatit" public corporation

Risk is a quantitative measure of danger. Anthropogenic-ecological risk determines the industrial nature dangers. General risk definition contains two parts as a rule: measure of possibility (probability, frequency) of the danger emergence and possible danger realization loss. Simple statement of danger emergence risk means that risk is a composition of possibility measure and loss.

Danger and risk classification may be performed with different criteria (*Bykov*, *Porfiriev*, 2006). This work actualized only basic research classes. There are admissible and inadmissible risks. Risk normalization is an independent problem (*Risk analyze problems*, 2004). Quantitative criteria of risk admissibility/inadmissibility are determined by the economical and social factors. Different countries have different values of them. Declaration of All-Russian social department "Russian scientific society of risk analysis" offers following standards for potential danger manufacturing entity of Russian Federation (*Frolov*, 2007):

– maximum permissible level of individual risk for population doesn't exceed 10^{-4} a year;

– maximum permissible level of social death risk of N and more people doesn't exceed $10^{-2}/N^{2}$.

Safety is absence of inadmissible risk. There may be marked out levels of safety that are determined by risk measure. Safety providing is the maintenance of admissible safety level.

Development safety is absence of inadmissible risk in the present and in the future according to the depth of forecast (short-term, medium-term and long-term). In such case along with the indeterminacy of risk measure there must be included (in one or another form) indeterminacy of forecast.

Safety management (risk management) is the choice of something adequate (reasonable and reachable) to the situation safety level.

Development safety management (development risk management) is the choice of situation-adequate safety level in the present and in the future determined by the depth of forecast.

The system of logically determined definitions is represented in Fig. 2.

3.2. Potential dangers structure of the mining complex

In order to build industrial ecological dangers structural models of the typical enterprise forming a company town we need:

– to reveal and to classify the main elements of the enterprise forming a company town that are important for safety;

– to reveal and to classify the main and safety-important types of the relations between the enterprise forming a company town elements;

– to determine the typical sources of the dangers and the influence objects of the enterprise forming a company town;

– to design the receiving and processing of the expert knowledge methodic that is oriented at basic models building.

Emergency conditions (accident, casualty) may be initiated by the anthropogenic, natural and social factors (and their combinations). Accident loss may be caused to the technosphere, nature and human. There are sources and objects of dangers different influence (anthropogenic, natural, social). As a result the common table "sources-receivers" is being built for the region or large enterprise that reproduces the nature of potential danger development. Table cells may be exposed to further analysis according to the management objectives. They are tables too in general (*Yakovlev*, 2001; 2004). Such multilevel system of embedded tables "danger sources – danger influence objects" represents hierarchical relative model of the region industrial natural complex potential danger development. This structure included sources and "receivers" links is more complex and more accurate model than traditional presentation of dangerous sources in the vector characteristic view (without "receivers").

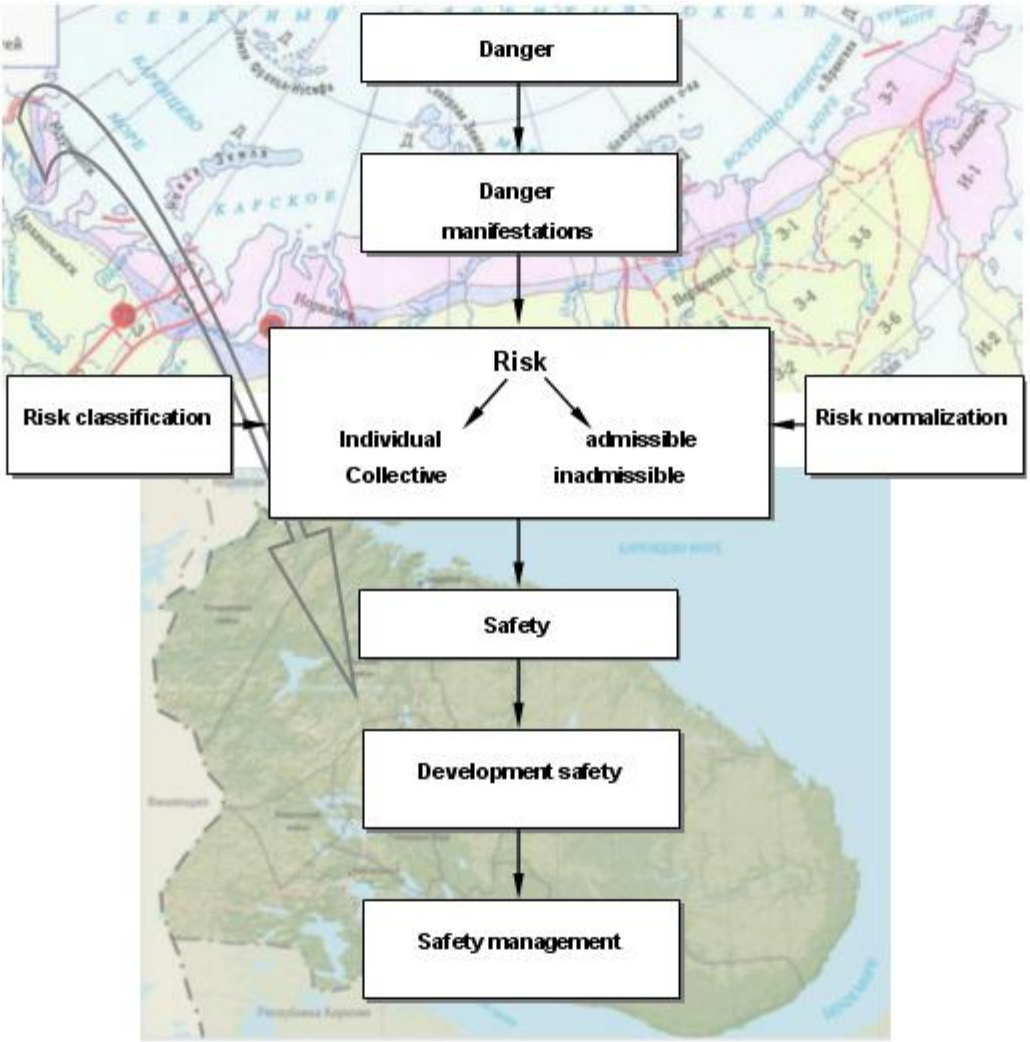

Fig. 2. Conceptual framework

The conventional simplified example of the table is shown in Fig. 3. Danger is "minus" and safety is "plus".

Receivers / Sources	1	2	3	4
1	+	–	–	–
2	–	–	–	+
3	–	+	–	+
4	–	–	–	–

Fig. 3. Table of dangers (example)

Now let's consider the formal description of the subject field. Suppose that there is set (industrial, natural, social, combined) of objects related to the enterprise safety defined. This set is finite. There is finite objects subset allocated from it. They are the sources of danger (potential influence subjects, dangerous objects): $S = \{s_1, s_2, \ldots, s_m\}$. There may be defined the finite subset of potential danger "receivers" (potential influence objects, "victims", "targets") for each source. Combination (by sources) of "receivers" subsets forms finite subset $R = \{r_1, r_2, \ldots, r_n\}$. Thereby mapping (correspondence) is defined as: A: $S \rightarrow R$. Then bearing set-combination is building $O = S \cup R$. One object could be source and receiver in time that is it could in both sets. So in general $S \cap R \neq \varnothing$. So that at the bearing set O there defined a set of ordered pairs (s, r), where $s \in S$ – source, $r \in R$ – receiver ($s, r \in O$). Ipso there defined relation H at the O. It is a subset of Cartesian product $H \subseteq O \times O$. Every element H is the ordered pair (s, r). This relation will be called the danger relation. If $(s, r) \in H$, then it will be written down this fact in the form of relation sHr, and s is in the relation H c r. Or shorter, s is dangerous to r. There is a conceptual representation of danger relation, which is represented below in Fig. 4.

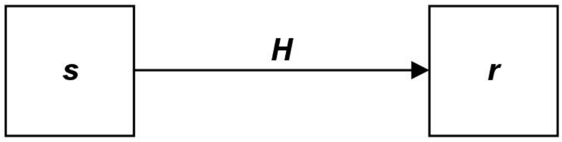

Fig. 4. Elementary danger relation

O set with its defined danger relation H, that is ordered pair (O, H), will be called basic (primary, reference) structural model of the industrial-natural complex dangers: $M = (O, H)$.

There are graphical and matrix methods of model definition along with the table method (Fig. 3). Let's renumber all elements of the set O: $O = \{o_1, o_2, \ldots, o_k\}$. Every element may be source and receiver. $o_i H o_j$ means that the first element is dangerous for the second in pair $(o_i; o_j)$. Advantage of such designation is equality of all elements from O set.

Let O set elements be the points at the plane – the vertexes of the future graph. Every point will be marked by the natural number – number of appropriate object. If the $o_i H o_j$ relation could be performed then we will build an arc (arrow) from i vertex to j. Oriented corresponded to M model graph $G(M)$ is obtained. Differentia of graphical method is clearness.

Fig. 5 represents the graphical variant (directed graph of the potential dangers) of the basic model corresponding to the table in Fig. 3.

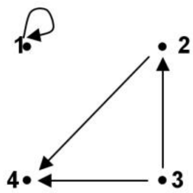

Fig. 5. Basic model directed graph (an example)

Let's build square matrix with the order $k \times k$. i row corresponds to the i element of O, j column – to the j element of O. 1 is on the meet if $o_i H o_j$ is performed and 0 is on the meet if not. Let o_{ij} be an element of this matrix. This matrix will be called the danger matrix. There is potential dangers matrix that corresponds Figs. 3 and 5 models which is shown in Fig. 6. This matrix is a adjacency matrix in graph theory. It may contain not only 0 and 1 but every natural number that is equal to the number of vertex corresponding joint arcs. This stage considers only the fact of danger presence (or absence) so that danger matrix could only contain 0 and/or 1. This means that the danger graph does not contain multiple (parallel) arcs. Matrix model presentation is convenient for computer realization and in case of large number of objects (graph vertexes).

$$\begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 1 & 0 & 1 \\ 0 & 0 & 0 & 0 \end{pmatrix}$$

Fig. 6. Dangers matrix (example)

Also model could be represented in the form of arcs list. Arc from the *i* vertex to *j* vertex will be represented as the ordered pair $(i; j)$. Then model in Figs. 3, 5, 6 could be represented as $M = \{(1; 1), (2; 4), (3; 2), (3; 4)\}$. Compactness is the advantage of such basic model definition.

Constructive method of model definition (building) described is the procedure of expert knowledge production and processing that is basic model forming oriented. Such models could be built with minimal information about danger sources and influence objects in technosphere, natural and social environment. Models are primary (basic). Elements and their relations are considered homogeneous actually.

3.3. Dangers quantitative characteristics

Basic model research is accomplished. The main target of research was to define quantitative characteristics of danger of both separated elements and mining complex in general. Herewith:

– qualitative comparative analysis of the different structure elements danger was made;

– quantitative danger measures of the structure elements were defined;

– qualitative comparative analysis of the different structures with the similar number of elements was made;

– qualitative comparative analysis of the different elements number structures was made;

– integral quantitative measures of the different structure dangers were defined.

Forming the quantitative characteristics of the elements and structure dangers allows us ranking elements by the danger power. Also it allows us performing comparative measuring of the alternative structure variants. The logical algebra application for the complex-structure systems at this point supports the production of uncommon and valuable results even in case of absence of the statistically reliable input information about accident probability and their possible losses. The last factor is especially important for the infrequent and large accidents and emergency conditions.

Elements dedicated of the mining complex also connected with another valuable relation types. Fix accounting and lay of land is essential for the both mining complex generally and some dangerous enterprise objects (for example, waterworks). Dangerous technological processes elapse; enterprise is developing and is updated. That's why time factor accounting is important in the operational and strategic aspect. Mining complex elements are built-in of the hierarchical enterprise organizational-managing structure so that such type of relations must be considered. Next dedicated elements are in multiple technological processes (mining, transporting, and concentration for example) that is linked by the technological relations. In order to account these relations basic model is completed with the following types of *O* set relations: *S* – special, *T* – timing, *Org* – organizational, *Tech* – technological. As a result generic basic model become $M = (O, H, S, T, Org, Tech)$. It might be interpreted as a set of models that account defined relation types. Real production processes are realized in the conditions of object region source data incompleteness and inaccuracy. That's why one could say about marked types realization (some or every) in a probability way. Basic model completes with probabilistic characteristics of the relations $P(C)$ as a result, where *C* is a type of relation. The existing methods of dangers and risks analysis and also algebraic systems theory methods are applied to the models research. In order to illustrate obtained structures there have been weighted graphs and bearing pseudograph used.

It is entered into consideration a random variable – a possible damage *X* from failures for any period of time (for example, a year) for the quantitative characteristic of danger of a source in relation to any object (pair characteristics "a danger source – the object of influence", i.e. a certain cage of the table) (*Yakovlev*, 2001). (It will be postponed for a time the dimension and also factors influencing distribution of *X* size question.) This size can be discrete and continuous. In a discrete variant the exhaustive *X* characteristic is a distribution number for example:

X	x_0	x_1	x_2	…	x_n
p	p_0	p_1	p_2	…	p_n

,

where $x_0, x_1, x_2, \ldots, x_n$ are the possible values of the random *X*, and it is applied that $x_0 = 0$ and $x_0 < x_1 < x_2 < \ldots < x_n$;

$p_0, p_1, p_2, \ldots, p_n$ – are the probabilities of specified values that is $p_0 = P(X = x_0), \ldots, p_n = P(X = x_n)$, therewith $p_0 + p_1 + p_2 + \ldots + p_n = 1$.

Thus, x_n value corresponds to the maximum failure, x_0 value corresponds to absence of failures, and events $X = x_0$, $X = x_1, \ldots, X = x_n$ form the full group. As a rule, for real dangerous objects higher damage corresponds to the smaller probability, i.e. the parity $p_0 > p_1 > \ldots > p_n$ is fair.

It is possible the use the numerical characteristics of distribution as danger indicators (for current cage). Natural generalization is consideration of the damage *X* as stochastic function of coordinates and time: $X = X(x, y, z, t)$. It allows us to carry out the analysis of dangers to spatial and dynamic systems that are the real industrially-natural systems. Other important advantage of such generalization is the possibility of mathematic expression of the numerous risks-indicators used in practice (number of victims, material damage, the size of the zone of defeat etc.), that characterizes various kinds of dangers and various level system, in common terms of corresponding stochastic functions of the damage. From the point of view of development safety modeling it is enough to be limited to research of stochastic function $X = X(t)$ at the first stage.

Then the problem of development of the general indicator for group of table cages (pairs) is solved. The unified mathematical description of safety of all subject domain is constructed as a result.

As a result for the determined enterprise or region the set of the models representing formalized "portrait" of dangers is formed depending on degree of a level of scrutiny of subject domain (dangerous processes and objects). This set forms a basis for decision-making support on management of industrially-ecological safety. It also allows defining directions of additional researches for replenishment and detailing of a set and elaboration of models and to prove a choice of rational level of safety. Depending on a management specific target this or that subset of models is staticized.

Thus, generalization of base models for the purpose of the account of existential and organizational-technological interrelations of mining complex allocated elements is developed. Also the account of uncertainty of the initial data is developed. The common method of management of the diverse dangers that is realized in a number of methodical workings out (*Yakovlev et al.*, 2011) for specific directions of the mining complex dangers analysis is founded.

4. Main theoretical and practical research results

4.1. The method of stability complex estimation to the influence of technogenic, natural and social emergency conditions of the enterprise forming a company town is developed. Technique feature is the account of not only diverse dangerous objects as a part of the enterprise, but also dangerous technological processes (for example, the turnover of dangerous substances). Emergency conditions influence on the ecosphere, technosphere and social sphere is estimated by the size of a possible loss. The complex matrix characteristic of the enterprise safety that is the basis of stability increase decision-making is being built as a result.

The complex estimation of the "Apatit" public corporation stability is performed on the basis of the offered method. There have been defined internal and external emergency conditions, established the basic damage factors, estimated the possible loss and revealed the weakest spots factors for the tail and chloric economy, a warehouse of the explosive materials, four mines, two apatite-nepheline concentrating factories, systems of power supply, buildings, constructions and the equipment. Results of estimation are intended for a substantiation of the stability-increase measures plan of the mine-chemical complex.

The following safety declarations of some region dangerous objects are developed with the application of this method: a warehouse of explosive materials, a chloric farm, storehouses of concentrating factories wastes, gas-filled stations.

4.2. Calculation of a possible accident loss is a necessary component of the enterprise and region industrially-ecological safety managing process. Hydraulic engineering constructions (HEC) of the mining enterprises are specific industrial potentially dangerous objects. The problem of the hydroconstructions risk analysis is actual due to the huge hydrodynamic accident loss (in Russia and abroad), a variety of HEC types and appointment and the preemergency condition of many domestic HEC. Full calculation of probable loss according to standard documents demands of the numerous initial data and represents rather labour-consuming research. That's why the express method of HEC failures consequence definition is developed. The following results are received during the method substantiation: the information model of calculation is constructed; definitions of the basic concepts are specified; possible calculation simplifying assumptions and the correct work-limiting suppositions are formulated; the probable loss definition algorithm is developed; the geoinformation technology usage is proved.

The method efficiency is confirmed during the probable loss calculation for the following complexes of "Apatit" public society: GTS of ANOF-2 with technological waste storehouse in Imandra Lake Belaya gulf, GTS of ANDF-3 with a similar storehouse on the Zhemchuznaya River, GTS of East mine with Koashvinsky and Norkpahksky open-cast mine wastes. There are natural and cost indexes of a possible accident loss (social, material, ecological) defined for the specified constructions. There are the heaviest and most probable accident scenarios revealed.

4.3. Implementation of information technology admits a necessary condition of industrial safety level increase, but it is carried out by rather slow rates, at the object level especially. It is become clean firstly by the complexity and (as consequence of) weak formalizing of subject domain, and secondly by the industrial safety specificity and novelty as management object. Limitation of financial resources of the enterprises and backwardness of the dangers automated monitoring network could be the constraining information subjective reasons. Interdisciplinary character of subject domain, an abundance of standard and acts, variety of dangerous objects and processes, absence of the dangers and risks approved design procedures, inopportuneness and the condition information unauthenticity must be noted.

These features have been considered within the development of the automated decision support system (DSS) model of industrially-ecological safety of a mine-chemical complex management.

Functional and information subsystems are defined within the model limits; initial requirements to the typical automated workplaces are formulated. A new and important part of model is the system of interface designing for the large enterprises industrial safety management decision-making support. System main blocks are the current version of the interface and the built in interfaces editor. The editor provides possibility of typical windows creation and change that allows to accelerate the DSS user properties debugging process. Specific appendices adaptation is made by means of specially developed adjustment interface.

Such structure allows to co-ordinate together the diverse dangerous processes and objects, and also functions of their management. It provides specific target or function management process adjustment or the specific expert support. It supposes adequate realization of DSS software structure.

Approbation of the received results is executed at creation of the "Apatit" public corporation industrial safety automated control system project. The increase of safety level at the expense of routine activity automation and the introduction of management practice information technology was the purpose of the work. Novelty and complexity of the project are caused by complex coverage of the enterprise basic dangers and also by the account of the experts work basic forms and directions. The computer model of a typical workplace of system is realized, thus the possibility of work with various information representation forms is provided for diverse dangerous processes and objects. The advantage of model is the possibility of information support operative formation to provide the decision-making of industrial safety enterprise forming a company town management.

4.4. The tooling software system of the possible anthropogenic-natural accidents express risk analysis is developed for typical operating and projected mining complex objects. The description of possible accidents is generated on the basis of processing of the diverse data about accidents and incidents on similar objects. The tentative estimation of their probability and the loss for the given object is performed. The following groups of accident characteristics are allocated: the reasons of accidents; the factors promoting occurrence and accident development; accident development scenarios (in the form of trees) from the source (initiating) event till liquidation of consequences; the loss (social, material, ecological). The unified structure of the accident anthropogenic-natural descriptions is offered.

Passports of the Murmansk region thirty diverse dangerous objects safety are developed with the application of this tooling software system.

The decision support information technology for the prevention and liquidation of anthropogenic accidents on objects consequences of oil refining is developed. Features of technology are the automated synthesis of typical objects accident scenarios and also the accident risk estimation accounted territory natural-climatic features.

Ten plans of the prevention and liquidation of oil floods and oil products from local to federal levels are developed on the basis of technology during the last years.

4.5. The information technology for regional industrial complex objects safety regulation adaptive system construction and support is developed. Features of technology are structural decomposition and the subsequent synthesis of criteria and safety requirements for typical classes of objects and regulation directions. A considerable quantity and heterogeneity both management possible objects and regulating regulatory legal acts are considered. The computer standard-methodical base of industrially-ecological safety regulation is realized. The structure is developed, classification and identification of potentially dangerous objects of a typical mine-chemical complex is performed. Necessary and sufficient safety requirements are revealed for each object type and a regulation direction.

The technology is approved on the example of "Apatit" public corporation fire safety declaring.

The program system intended for formation and support 3D-models of industrially-natural complex superficial objects is developed. The application of relief modeling typical software products and the construction preliminary varied in form and complexities of building and construction models is proved. Original software of mining complex three-dimensional geoimages of typical objects creation support is developed.

The program system is approved at the example of Hibinsky mining area. Vector and frame models of the relief and infrastructure objects are realized on the basis of the cartographical information and space shooting.

5. Conclusion

In this paper the unified integrated approach and technologies for problem solution of the information and analytic support of the industrial nature complexes risk-stable development have been described. Constructive definitions of the main concepts have been given. Models of industrial ecological danger developments have been designed. Quantitative measures of the elements and structure dangers are defined. Introduced methods and information technologies were approved at the example of one of the largest mining complex of the Murmansk region, the enterprise forming company towns Kirovsk and Apatity – "Apatit" public corporation.

Institute risk analysis developments were awarded by the 10th anniversary exhibition-congress "High technology. Innovations. Investment" silver medal (S.-Petersburg, 26-29 of September 2005) and VIII Moscow international innovations and investment show gold medal (Moscow, 3-6 of March 2008).

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