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The information model of technogenic risk management

V. Lyfar

Volodymyr Dahl East Ukrainian National University, e-mail: atp01@ukr.net

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Summary. The article is devoted to the development of technogenic risk management models and formalization of the process of support in making decision in the sphere of industrial safety. The structural, informative and mathematical models, used to process information in the technological risks management, as well as a formal model of the process of support of making decision in achieving an acceptable level of technical risk are presented and analyzed.

Key words: technogenic risks, information technology, control model, Seveso III, simulation, multiparametric optimization, Pareto space.

INTRODUCTION

Technogenic risk management is based on understanding of the potential danger inherent in the technogenic objects and making strategic decisions initially and subsequently developing of organizational, technical, economic and other measures that demonstrably lead to an acceptable level of risk. The term "acceptable risk" refers to the relatively tolerant expected impacts from potential threats specific for the high-risk objects (HRO) [1, 2]. It is important to fully reimburse the expected consequences if an accident occurs and does not reduce the rate of development of society. Thus, the most important part of modeling in risk assessment is the development of criteria and quantitative indicators of "acceptable risk", as datains for limitation of space in making decision [3-6].

RESEARCH OBJECT

This article focuses on the development of technogenic risk management models and formalization of the process of support in making decision in the sphere of industrial safety. The structural, informative and mathematical models, used to process information in the technological risks management, as well as a formal model of the process of support of making decision in achieving an acceptable level of technical risk are presented and analyzed [7-8].

RESULTS OF RESEARCH

Information support of the assessment and technogenic risk management is implemented through the development of reporting information formats and formalization of the data conversion process so that:

- to get the criterial parameters constraints of risk space $Rp = \{p_i\}$,

- to assess current risk indicators due to performance combined study of HRO for the risk function $R = \langle \vec{\theta}, \vec{P}, \vec{M} \rangle$,

- to establish a correspondence between risk indices and the input element of the perturbation of complex chemical-technological system (CCTS) and transitions to states for s perturbation, thus completely defined function $In : B(O) \rightarrow P.$ characterizes the probability of transition system from one state to another with corresponding perturbation (refuse/ failure or wearing-out of CCTS elements) [9-11],

- to select subset of emergencies which present an unacceptable level of risk $Am = \{a_j\}$,

- to determine the probability of occurrence of these situations $Ps = \{ps_j\}$,

- to identify great number of accident scenarios, based on the probability of failure (activation) $k-$ th of facilities of protection $Sc = \{pc_k\}$,

- to determine the physical processes that constitute a threat $\vec{\Phi}$ for scenarios Sc ,

- to simulate these processes and quantify the losses and integral risk factors [11, 12-15],

- select a subset of emergencies corresponding to acceptable level of risk $An = \{a_r\}$,

- to make analysis of the cause-and-effect processes of origin/emergence and development of these accidents and to allocate a plurality of blocks CCTS of RHO $Bl = \{b_q\}$, for developing measures that will improve the reliability (lower risk) of trouble-free operation [16-17],

- to execute the process of making the selection, taking into account the optimization on the basis of risk indicators, to identify the subset of solutions $Tr = \{t_{opt}\}$,

- to execute re-modeling, taking into account the changed elements of the reliability parameters CCTS on condition of adoption of the proposed solutions and to ensure in the acceptability of integrated risk indicators.

The scheme of informative model of technogenic risk management is shown in Fig. 1.

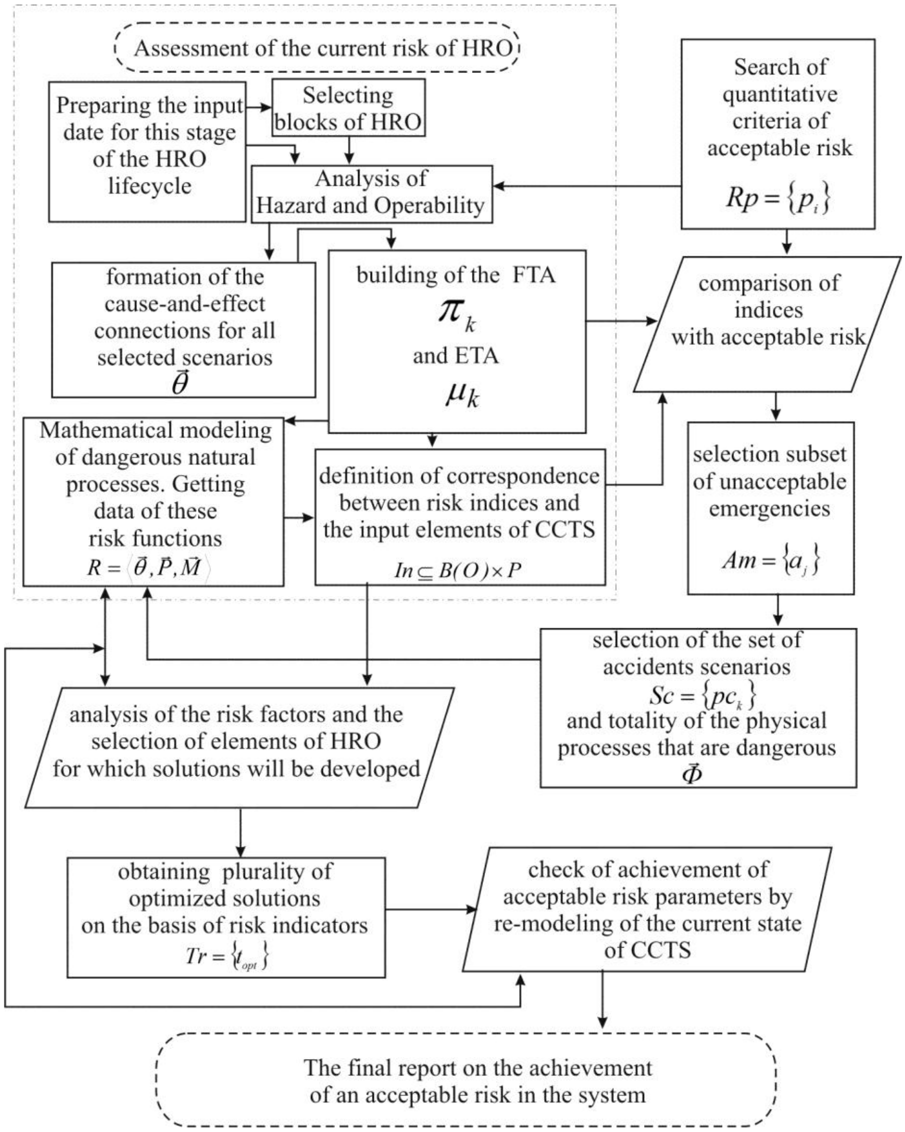

Fig. 1. The scheme of informative model of technogenic risk management

To assess the current technogenic risk at the given stage of the life cycle of HRO it is necessary to define the purpose of the study and to make a structure of the data so, as to establish the exact relationship between the input data, all phases of the study, the used models, the obtained results, the methods of analysis and research outcome indicators. Transparency must be ensured in all the process of research and justification of the recommendations and decisions. Thus, it is necessary to provide the structural stability of study.

Firstly, the object must be identified as a dangerous one. To do this, Seveso III Directive [18, 19] provides a procedure of classification of enterprises (Art. 3, Appendix 1) by "lower" and "higher" levels of risk. Initial identification is performed by comparing the characteristics and quantities of hazardous substances circulating in the production, storage and transportation with the tabular data presented in the Seveso III directive applications. In addition to high-risk facilities identified by the method mentioned above, it is necessary to take into account special cases, in which the possible use of dangerous substances or technologies are not classified according to Seveso III as HRO, but at the same time to be a threat to a large number of people.

The structural model for the identification of Seveso III HRO and model of processes information support are shown in Fig. 2.

Generalized model of technological risks management is based on the specific processing of data provided by cortege:

$$MTR = \langle Tp, R, In, F(m), Tr, M, Macc \rangle, \qquad (1)$$

where: $Tp = \{tp_j\}$ − the plurality of process units and elements of the CCTS owned by the selected HRO, R − the risk function, typical for the considered elements of HRO, $In \subseteq B(O) \times P$ − correspondence between the input elements of the HRO and transition probabilities in a state of emergency for perturbation blocks,

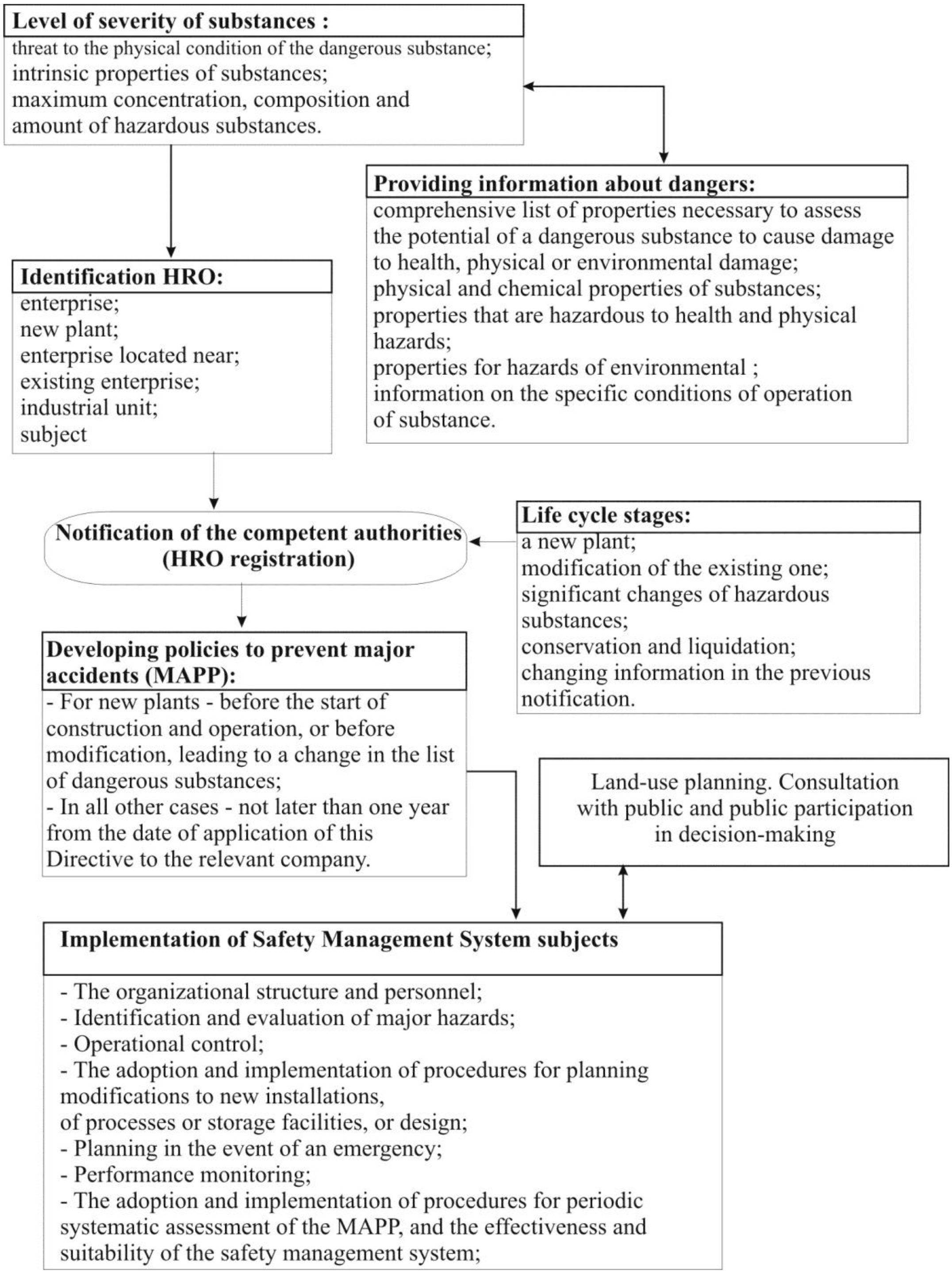

Fig. 2. The structural model of information support for the Seveso III directive

$F(m)=\{f(m_i)\}$ − the selective function of the current required model for the corresponding *i*-th state of the system,

$Tr=\{tr_a\}$ − many decisions regarding the elements of the CTS, affecting on the risk mitigation system,

$M=\{mp_z\}$ − many consequences of emergency processes $z \in 1 \ldots A$, which are typical to the investigated sources of danger (HRO blocks).

$Macc=\{ma_c\}$ − many risk constraints that are considered to be "acceptable".

The task is formulated as follows: the risk function is represented as:

$$R=\langle \vec{\theta}, \vec{P}, \vec{M} \rangle, \tag{2}$$

where: $\vec{\theta}$ − a vector parameter that defines the accident scenario,

$\vec{P}=\left[P_t,P_i,P_{soc}\right]^T-$ a vector of probabilities of adverse consequences,

$\vec{M}=\left[C_{des},N_{ded}\right]^T-$ a parameter vector of effects that characterize the damage and a number of people affected by the accident. Let CCTS consist of ***i*** subsystems, then for any ***i***-th subsystem the risk is determined by:

$$R_{ki}=\left\langle \vec{\theta}_k,\vec{P}_{ki},\vec{M}_{ki}\right\rangle. \tag{3}$$

Supposed that it is known:

− deterministic models of physical processes that may occur in the i-th subsystem, $f_{ij}:\vec{S}_{ij}\rightarrow\vec{\Phi}_{ij},\ j=1...J$ (the set of elementary events leading to the accident), where $\vec{S}_{ij}$ − the parameter vector defining the initial state of the i-th subsystem; $\vec{\Phi}_{ij}$ − the vector of phase variables of elementary physical processes that may occur in the i-th subsystem in the accident,

− model to estimate the probability of occurrence of stochastic elementary events: $Pr_{ij}:\left(\vec{S},\vec{\Phi}\right)_{ij}\rightarrow\vec{P}_{ij},\ j=1...J$, where $\vec{P}_{ij}=\left[P_{ij}^{des},P_{ij}^{ded}\right]$ − the vector of probabilities of destruction and of human losses.

We consider the complex model of emergency CCTS for the analysis and prediction of consequences of technological accidents, including:

− model based on Bayesian approach to estimate the probability of occurrence of adverse events in the i-th subsystem in the form of "fault tree" − $\pi_k:\left(\left\{\vec{P}_{ij}\right\},\vec{\theta}_k\right)\rightarrow\vec{P}_{ki}$,

− simulation model (model of discrete-event) an accidents in the form of "event tree" − $\mu_k:\left\{\left(S,\Phi,\vec{P}_k\right)_i,\vec{\theta}_k\right\}\rightarrow\vec{M}_{ki}$, где $S_i=\left\{\vec{S}_{ij}\right\}$, $\Phi_i=\left\{\vec{\Phi}_{ij}\right\}$,

$\vec{M}_k=\sum_i\vec{M}_{ki}$ − integrated indicators of damage from the study k-th potential accident [20, 21].

To solve the problem of multi-parameter optimization it is necessary to apply Pareto dominance methods to search for the dominant solutions. Multi-criteria optimization task is seen as a problem of simultaneous optimization of all partial criteria. It's required to find a set of solutions $\vec{x}\in X$, the minimum for all of these criteria in some sense. In other words, the following optimization problem is considered: $g^{(k)}(x)\rightarrow min$, $k=\overline{1,N}$, on condition $x\in X$. At the same time the criteria $g^{(k)}(x)$ are *partial criteria*. They can be seen as a set of vector criterion $G(\vec{x})=(g^{(1)}(\vec{x}),...,g^{(N)}(\vec{x}))$ and it is a subject to be optimized (for each individual component or privately).

The ideal situation in solving multi-criteria optimization is the case when the intersection of the sets of optimal solutions for all particular criteria is not empty. This set is denoted as follows: $\bigcap_{k=1}^{N}Arg\,\min_{\vec{x}\in X}g^{(k)}(\vec{x})$.

As a rule, such a compromise solution they are trying to find in the class of so-called effective solutions (also called Pareto efficient solutions).

The set of all accidental situations should be allocated, where a risk of exceedances is over the acceptable ones:

$$M_k^{*}=M_k\setminus Macc=\left\{m/m\in M_k\ u\ m\notin Macc\right\}. \tag{4}$$

If the selected set is not empty, it is necessary to carry out the search process solutions for all of its elements using Pareto's optimization in the space techniques.

The main purpose of risk monitoring is to detect changes and abnormalities in the current state of risk throughout the duration of the period between the procedures of the internal audit of technical risk of the HRO.

In addition, the result of monitoring of risk should be a reaction to the events and processes that increase the risk factors above permissible. In general, this reaction manifests itself in the form of initiation and conduct preventive repair work (PRW).

The main purpose here is not only the realization of ALARP principle, but also the realization of PRW on a "repair as needed". In this connection, in the process of monitoring procedures are carried out periodically RBI-analysis for those elements CCTS that alter or may alter the reliability performance.

Risk monitoring is carried out within the enterprise industrial safety policy is part of the safety management system and is the systematic collection and processing of information that can be used to improve the decision-making process, as well as, indirectly, to inform the management of (public) or directly as a tool feedback for the implementation of projects, the evaluation of programs or policy. He carries one or more of the three organizational functions:

- identifies critical condition or in a state of change in production processes, in respect of which will be developed in the future course of action,

- it establishes a relationship with the environment, providing feedback on previous successes and failures of specific policies or programs,

- establishes compliance with the rules and contractual obligations.

Monitoring the level of industrial safety condition for the realization of all three functions and it should be organized on the basis of clearly defined critical indicators. These indicators (local number) are identified and described in the analysis of the input data of industrial safety management systems and hazard and risk analysis for all major hazard, particularly in industry. For each indicator is assigned a quantitative or qualitative value (critical level) or multiple values, the overcoming of which gives the opportunity to make a conclusion about the need to take action on the process, that characterized by a set of parameters analyzed.

All options must be present in the document management system of industrial safety and databases.

For those technological elements (represented in the "fault tree"), that affect the level of risk of HRO to a large extent, it is necessary to extend the definition of reliability indicators (probability of failure). Data on the reliability of the elements of the process, the level of staff training to be collected on the basis of questionnaires. Perhaps the use of passport data of individual elements of the HRO or average data published in the relevant documents. The structure of the information risk monitoring process is shown in Fig. 3.

For most elements CCTS involved in stochastic processes, the reliability of data can be obtained as follows:

For each selected item for which you want to know the probability of failure, you must gather the following information:

T_a – average uptime of equipment (instruments, devices) h,

λ_a – the average intensity of the flow of failures of equipment (instruments, devices) 1 / h,

$$T_a = \left(\sum_{i=1}^{N} T_i \right) / \text{N}; \ \lambda_a = 1/T_a,$$

where: T_i – actually spent time in i - th period, h, N – the number of failures that occurred during the test time (working periods).

Thus: $Q(t) = exp(-\lambda_a t)$,

where: $Q(t)$ – probability of failure-free operation during the period t.

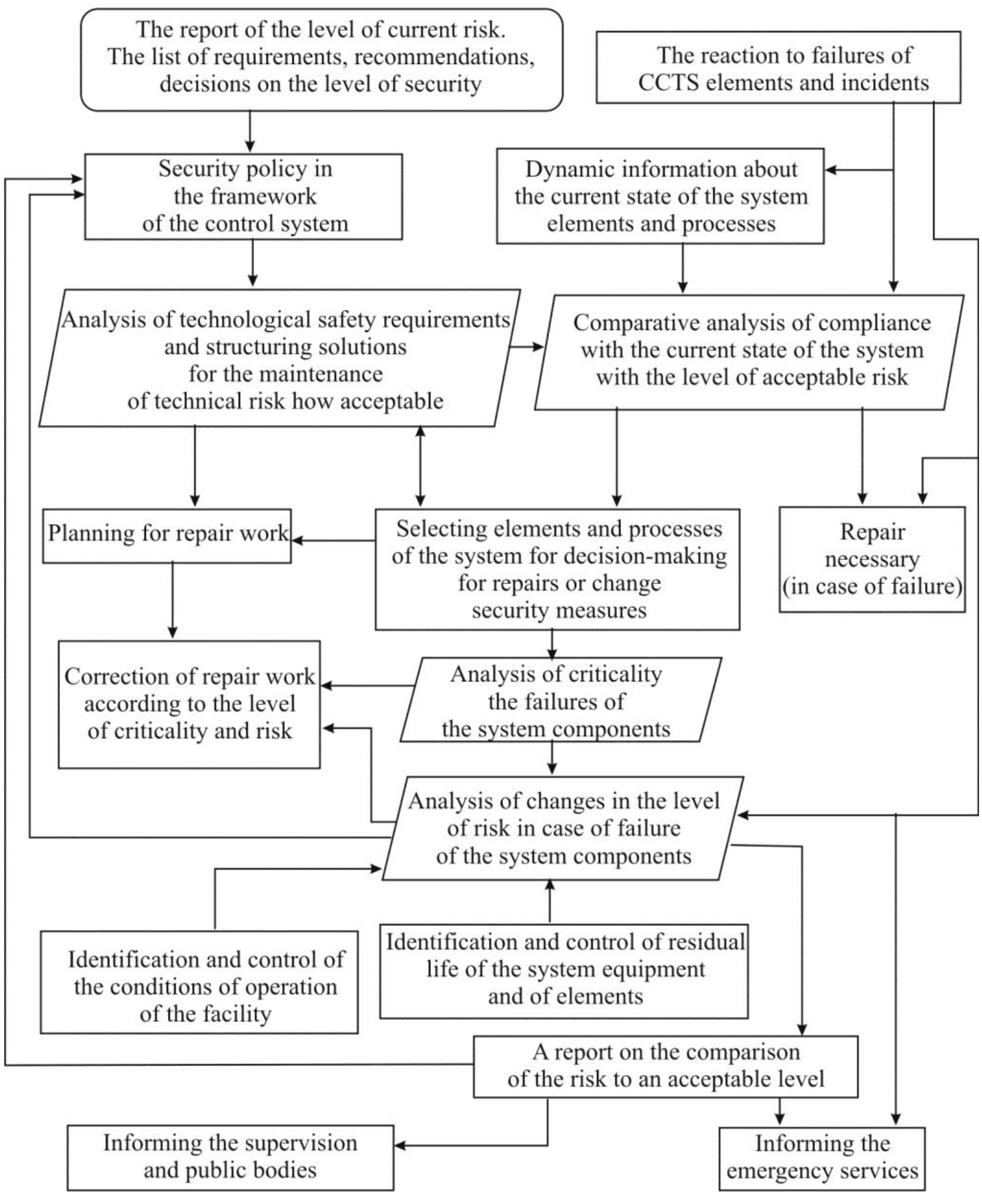

Fig. 3. Information risk monitoring process in the structure of industrial safety management system

$P(t) = 1 - exp(-\lambda_a t)$ – the probability of failure for a period t.

The individuality of each piece of technological equipment GCO manifested in the difference between the process parameters and operating conditions, load conditions, structural and material performance. Observe the technical condition of the equipment is mostadvisable in the performance of works related to the frequency of emergency risk assessment for the equipment, which is a long time in operation.

It is at this stage of the life cycle of process equipment ignoring damage, "disease", accumulated in the process of a real long-term operation, significantly distorts the results of the risk assessment, reducing their objectivity and does not contribute to the development of corrective actions to a dangerous object.

CONCLUSIONS

1. The following information is intended for the creation and operation of information technology support decision-making in the management of technological risks.
2. The information model allows formalized the risk management process on the basis of objective risk indicators.
3. The implementation of information technology risk management is possible in the case of the development of software system and database, which will allow to automate processes in the search space of a Pareto solutions.

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ИНФОРМАЦИОННАЯ МОДЕЛЬ УПРАВЛЕНИЯ ТЕХНОГЕННЫМ РИСКОМ

Владимир Лыфарь

Аннотация. Статья посвящена разработке моделей управления техногенным риском и формализации задачи процесса поддержки принятия решений в области промышленной безопасности. Представлены и проанализированы структурные, информационные и математические модели, используемые для обработки информации при управлении техногенным риском, а также формальная модель процесса поддержки принятия решений по достижению приемлемого уровня техногенного риска.

Ключевые слова: техногенный риск, информационная технология, модель управления, Seveso III, моделирование, многопараметрическая оптимизация, пространство Парето.