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A NEW PARADIGM OF DIGITAL TRANSFORMATION OF SMART MANAGEMENT OF MULTIPARAMETRIC SYSTEM

КӨП ПАРАМЕТРЛІК ЖҮЙЕЛЕРДІ БАСҚАРУДЫҢ СМАРТ ТҮРЛЕНДІРУДІҢ САНДЫҚ ЖАҢА ПАРАДИГМАСЫ

НОВАЯ ПАРАДИГМА ЦИФРОВОЙ ТРАНСФОРМАЦИИ СМАРТ УПРАВЛЕНИЯ МУЛЬТИПАРАМЕТРИЧЕСКИМИ СИСТЕМАМИ

Abstract. The purpose of this work is to improve the quality of the management process of the monitoring territorial service and prevention of emergency situations system. The goal is to solve the problem of the management system by improving the information and analytical support. In the proposed study, two scientific and practical tasks are solved: the development of a formal method for quantifying the quality of management of a complex multi-criteria organizational and technical system under conditions of statistical uncertainty of management agents; formalization of the process of quantitative assessment of decision-making risks in the environment of statistical uncertainty of management agents. Probabilistic and simulation models have been developed to solve the tasks of assessing and predicting the risks of control and decision-making, under conditions of statistical uncertainty. The verification of theoretical prerequisites is implemented by computer modeling using a software application developed for these purposes. The developed multi-approach methodology of integrated quantitative assessment of the quality of management of the territorial system of monitoring and prevention of emergency situations is new in the class of solving such problems.

Keywords: management; emergencies; process; model; risk; distribution law; information; uncertainty, monitoring.

Аңдатпа. Жұмыстың мақсаты – төтенше жағдайлардың мониторингі және алдын алу бойынша аумақтық қызмет жүйесін басқару процесінің сапасын арттыру. Менеджмент жүйесін ақпараттық-аналитикалық қамтамасыз етуді жетілдіру арқылы мақсатқа жету ұсынылып отыр.

Ұсынылған зерттеуде екі ғылыми-практикалық міндет шешілді: басқару агенттерінің статистикалық белгісіздігі жағдайында күрделі көп критериалды ұйымдық-техникалық жүйені басқару сапасын сандық бағалаудың формальды әдісін жасау; бақылау агенттерінің статистикалық белгісіздігі жағдайында шешім қабылдау тәуекелдерін сандық бағалау процесін ресімдеу.

Бақылау және шешім қабылдау тәуекелдерін бағалау және болжау міндеттерін шешу үшін статистикалық белгісіздік жағдайында ықтималдық және имитациялық модельдер әзірленді.

Теориялық болжамдарды тексеру осы мақсат үшін әзірленген бағдарламалық қосымшаны пайдалана отырып, компьютерлік модельдеу арқылы жүзеге асырылады.

Төтенше жағдайлардың мониторингі мен алдын алудың аумақтық жүйесін басқару сапасын кешенді сандық бағалаудың әзірленген көп жақты әдістемесі осындай мәселелерді шешу класында жаңа болып табылады.

Түйін сөздер: басқару; төтенше жағдайлар; процесс; модель; тәуекел; бөлу заңы; ақпарат; белгісіздік, мониторинг.

Аннотация. Целью работы является повышение качества процесса управления системы территориальной службы мониторинга и предурпреждения чрезвычайных ситуаций. Достижение цели предлагается решать путем совершенствования информационно-аналитического обеспечения системы управления. В предлагаемом исследовании решаются две научно-практические задачи: разработка формального метода количественного оценивания качества управления сложной многокритериальной организационно-технической системой в условиях статистической неопределенности агентов управления; формализация процесса количественного оценивания рисков принятия решений в среде статистической неопределенности агентов управления. Для решение поставленных задач оценки и прогнозирования рисков контроля и принятия решений, в условиях статистической неопределенности, разработаны вероятностная и имитационные модели. Проверка теоретических предпосылок реализована компьютерным моделированием с использованием программного приложения, разработанного для этих целей. Разработанная многоподходная методика интегрированного количественного оценивания качества управления территориальной системы мониторинга и предупреждения чрезвычайных ситуаций является новой в классе решения подобных задач.

Ключевые слова: управление; чрезвычайные ситуации; процесс; модель; риск; закон распределения; информация; неопределенность, мониторинг.

Introduction. Current trends in digital transformation of socio-economic processes. Solving complex managerial problems in practical management remains impossible without the use of new digital information technologies [1,2]. Information technologies play a special role in decision-making processes, which include all stages of management processes. Emergency management system is one of areas where scientific and technical methods are intensively used and developed. With the advent of space tools, new information technologies, robotics, unmanned aerial vehicles (UAVs), artificial intelligence (AI), big data (BI) and VLC technologies, the managing business processes principles in operational organizations in this field have changed, monitoring and control of emergency situations [5].

Currently, attention has been drawn to the fact that emergencies and subsequent hazards such as fires, floods, and floods cause huge losses, especially in the agricultural sector, where these events put large areas of suitable fertile land out of production or stop planned operations. Improving the quality of analytical functions in developed information systems is solved by intellectualizing data processing processes. It is true that all intelligent technologies have the concept of "SMART", which is interpreted as "SMART" or "thinking" [6-8]. Often, this concept is given the meaning of another term "convergence" and robustness, which is also used in literature and research [9, 10].

Recently, a new form has appeared in the field of emergency management and control, where the control of natural and man-made hazards plays a key role, a system with the general name - "Agriculture". The phrase "agriculture" appeared relatively recently [5].

Relevance. The research methodology is based on the geosystem approach. In this interpretation, the geosystem is considered as a special class of management agents of the system, where natural agents are systematically connected with each other and interact with the cosmic sphere and human society as a certain whole. In the tasks of assessing and predicting the dynamics of natural phenomena, the following are used as applied tools for formalization of geosystem approach methods: expert assessments, geographic similarities, functional dependencies, probabilistic and simulation models, fuzzy sets, agent-based approaches.

The issue of receiving, processing, transmitting and protecting information is very important in currently used information-analytical systems. Information and analytical support of complex multi-parameter stochastic programmable control systems with control factors and the problem of control and decision-making in conditions of statistical uncertainty of vague data is particularly relevant.

Scientific news. A new approach to solving information security problems at the technical level is solved using VLC technologies [3]. The statistical uncertainty of the factors and parameters of control agents leads to the emergence of risks at the decision-making stage.

This fact cannot be eliminated, therefore, in the latest edition of the ISO 2015 standard, regardless of the industry and legal subordination, in each new project, the manufacturer's risk and the consumer's risk are differentiated, and the quantitative assessment of risks is necessarily regulated.

This problem can be solved only by using mathematical apparatus and computer technologies. This problem is especially relevant in the systems of ensuring and preventing the safety of socio-economic objects from natural and man-made threats.

Organizationally, this is solved by creating special state and territorial services. Risks arising in decision-making stages in these organizations and situations are accompanied by huge costs for the population, therefore risk prediction and monitoring at a new scientific and technical level is an urgent task. Special automated systems of territorial management have been created and are being improved to ensure monitoring and control processes of natural and man-made threats in the environment. The basic version includes the structural-functional model of modern automated control systems [9, 10].

The peculiarity. Hardware in computer technology is structured and schematically resolved according to functional design goals. In automated control and monitoring systems of natural and man-made hazards, much scientific and practical attention is paid to instrumental control and measurement equipment. The scientific and practical feature and novelty of the work is the use of space monitoring tools, which are considered not as a local agent in the technological process of management, but as a target integration with multi-agent support in the system process.

Mathematical software is aimed at solving technical and economic problems of general systemic nature and operational technological level. The software determines the SMART level of the system. The latter includes management and control risk assessment and forecasting. Mathematical software in modern SMART systems plays a key role and determines the level of its "intelligence".

Innovativeness. On the basis of software provision, the system will have an applied technological purpose, which will provide the functions of the planned ideas.

The importance of work. Information provision of the system has its own disciplinary features and significantly affects the goals and principles of its design and use. In the concept of this system, it is necessary to implement general management from one center and to consolidate general technical and economic information. Information necessary for current technological purposes is concentrated in the database of local control centers.

Discussion. Organizational and methodological provision in accordance with legal norms, industrial and socio-economic conditions requires specific solutions and methods in each specific case.

Due to the high requirements for the accuracy and safety of the system in question, there are high requirements for metrological support. Due to insufficient knowledge on this issue, special research is needed. The metrological requirements of the ISO 9001:2015 standard were used in this work.

There is a random error in the measurement procedure [3]. The most important characteristic of random error is the distribution law. Research shows that random error can be approximated by three laws: Gauss's law, Weibull's law, and the law of equal probability.

In general practice, observational errors are often considered to be due to measurement errors. Control errors are estimated as the probability of false and undetected defects of R_{fd} and R_{ud} and are called producer and consumer risk [4]. Quantification of R_{fd} and R_{ud} approximation depends significantly on the probability distribution patterns between all the mentioned factors in their plural combination (composition). Each version of the combination of distribution laws is described by a specific mathematical or simulation model. The choice of distribution laws depends on the specific experimental task and is determined experimentally. The multi-parameter and specificity of the requirements for the quality management system of business processes in the emergency management environment requires an optimal approach to the selection of control process parameters. This problem cannot be verified by formal methods and numerical techniques.

The calculation shows that the number of all possible combinations (compositions) of statistical characteristics, laws and regulatory conditions, when they are fully sorted, amounts to 729 options.

In the proposed work, only some compositions of approximation options that adhere to the goals and objectives will be considered in the system of monitoring and control of natural and man-made hazards in the scope of practical feasibility.

Consider the main methodological options for risk control and formation when assessing and forecasting natural and man-made hazards.

One time limit. The initial stage of modeling studies the option of one-time limitation of the parameter "from below" controlled by the St norm (Fig. 1).

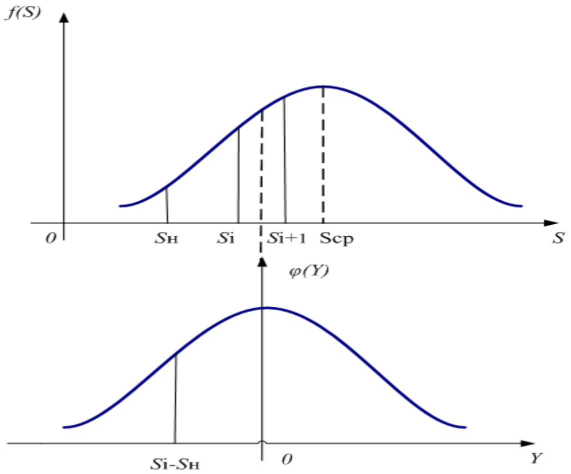

Figure 1. Single limit.

The parameter and error distribution density is as follows:

$$f(S)=\frac{1}{\sigma_S\sqrt{2\pi}}\cdot e^{-\frac{(S_i-S_{cp})^2}{2\sigma_S^2}} \quad \phi(Y)=\frac{1}{\sigma_\varphi\sqrt{2\pi}}\cdot e^{-\frac{Y^2}{2\sigma_\phi^2}}$$

Mathematical expressions for approximation errors R_{fd} and R_{ud} have the following form:

$$P_{лб} = \sum_{t=1}^{n} \frac{1}{\sqrt{2\pi}} \int_{t_i}^{t_{i+1}} e^{-\frac{t^2}{2}} dt \cdot \frac{1}{\sqrt{2\pi}} \int_{z_i}^{+3} e^{-\frac{z^2}{2}} dz$$

$$P_{нб} = \sum_{t=1}^{n} \frac{1}{\sqrt{2\pi}} \int_{t_i}^{t_{i+1}} e^{-\frac{t^2}{2}} dt \cdot \frac{1}{\sqrt{2\pi}} \int_{-z_i}^{-3} e^{-\frac{z^2}{2}} dz$$

Probability calculation according to the proposed formulas is carried out in the software complex of computer modeling. The analysis of simulation results shows that the value of R_{fd} is often dependent on the standard value and can reach 30%. The probability of R_{ud} also depends on the standard size and can reach 15%.

The result of the work. Development of a universal model for estimating and predicting control errors. In well-known studies, it was assumed that the standards of the lower S_l and upper S_u are symmetrical with respect to the average S_a of the monitored parameter. However, in practice this condition is not always correct and is not observed. Therefore, it is necessary to consider the hypothesis about the free location of the standards in relation to the observed average parameter. Figure 2 shows a graphical scheme of probabilistic modeling in the given conditions.

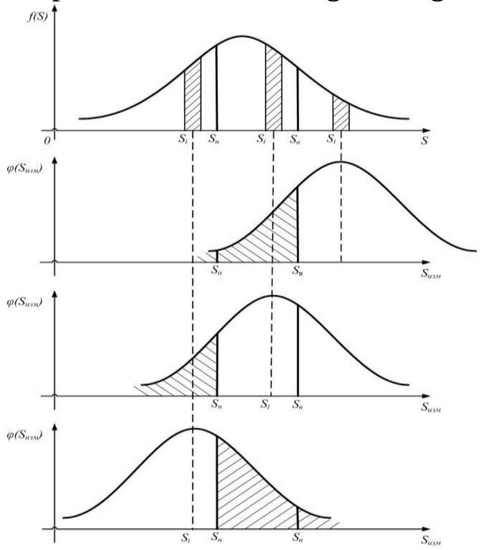

Figure 2. Formation of errors during the free placement of standards in the field of the monitored parameter.

To develop an approximation model, the range of S parameter values is divided into a certain number of discrete values from Sa - 3Ϭs to Sa + 3σs. An admissible case is considered when the true value of the parameter S is greater than S_l, but less than S_u.

In this example, we propose a hypothesis about the obedience of the studied indicator s to the Weibull law with a distribution density function

$$f(S,\alpha,\beta,\gamma) = \frac{\beta}{\alpha}(S-\gamma)^{\beta-1} \cdot e^{-\frac{(S-\gamma)\beta}{\alpha}}, \ S \geq \gamma$$

The integral distribution law is as follows

$$F(S) = 1 - e^{-\frac{(S-\gamma)\beta}{\alpha}} \quad (1)$$

Knowing the form of the integral function F(S), we can write for the value j of the parameter S:

$$P_{i\text{лб}} = \Delta F_i \cdot \left[\int_{S_i - S_{\text{в}}}^{-\infty} \varphi(y)dy + \int_{S_{\text{в}} - S_i}^{+\infty} \varphi(y)dy \right] \quad (2)$$

(2) After substituting the expression ΔFi into the integral function, we get (1).

$$P_{i\text{лб}} = \left(e^{-\frac{S_i^{\beta}}{\alpha}} - e^{-\frac{S_{i+1}^{\beta}}{\alpha}} \right) \cdot \left[\int_{S_i - S_{\text{в}}}^{-\infty} \varphi(y)dy + \int_{S_{\text{в}} - S_i}^{+\infty} \varphi(y)dy \right]$$

By organizing the collection of R_{fd} according to the range of values of S, we get the approximate value of R_{fd}:

$$P_{\text{лб}} = \sum_{i=1}^{k} \left(e^{-\frac{S_i^{\beta}}{\alpha}} - e^{-\frac{S_{i+1}^{\beta}}{\alpha}} \right) \times$$

$$\times \left[\frac{1}{\sigma_y \sqrt{2\pi}} \int_{S_{\text{н}}}^{S_i - 3\sigma_y} e^{\frac{y^2}{2}} dy + \frac{1}{\sigma_y \sqrt{2\pi}} \int_{S_{\text{в}}}^{S_i + 3\sigma_y} e^{-\frac{y^2}{2}} dy \right]$$

Making calculations, as in the previous case, we write for R_{fd}

$$P_{\text{нб}} = \sum_{i=1}^{k} \left(e^{-\frac{S_i^{\beta}}{\alpha}} - e^{-\frac{S_{i+1}^{\beta}}{\alpha}} \right) \cdot \frac{1}{\sigma_y \sqrt{2\pi}} \int_{S_{\text{н}}}^{S_i - 3\sigma_y} e^{-\frac{y^2}{2\sigma_y^2}} dy +$$

$$+ \sum_{i=1}^{k} \left(e^{-\frac{S_i^{\beta}}{\alpha}} - e^{-\frac{S_{i+1}^{\beta}}{\alpha}} \right) \cdot \frac{1}{\sigma_y \sqrt{2\pi}} \int_{S\text{в}}^{S_i + 3\sigma_y} e^{-\frac{y^2}{2\sigma_y^2}} dy$$

To study the level of risks of the statistical parameters of the models, a software application was created and a computer experiment was conducted. Figure 3 shows one of the results of modeling the risk formation process in the control system

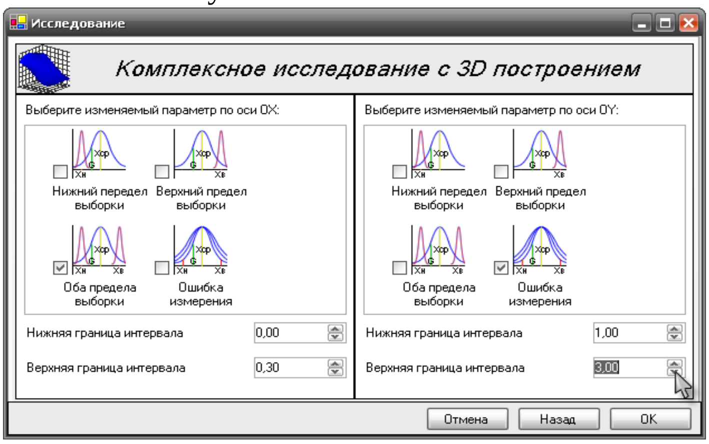

Figure 3. The results of the study of the risk formation model in the control system.

As can be seen from the graphs, the false defect approximation is more sensitive and depends on the variable ratio of the error to the tolerance value. The overall control reliability (upper curve) is particularly sensitive to the ratio of the uncertainty of the error to the uncertainty of the monitored parameter, which decreases to the 50% level. The increase in the quality of monitoring is reflected in the tightening of regulations.

Conclusion. An approximate model of control and decision-making risk assessment and forecasting was created in the context of statistical uncertainty in the scope of the tasks. A software application was created and a computer experiment was carried out to check the compatibility of the theoretical prerequisites with the experimental conditions. During the computer experiment, it was found that the risk can exceed 30% when the value of the measurement uncertainty corresponds to the accuracy of the uncertainty of the monitored parameter. In addition, it was found that the impact of uncertainty of standards is greater than the impact of measurement uncertainty.

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