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OPTIMAL RISK MANAGEMENT TECHNOLOGY AS A TOOL FOR ENSURING THE RELIABILITY OF SOLUTIONS MADE IN THE DIGITAL ECONOMY

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The modern stage of risk management development is marked by discrepancy between the implemented risk management systems and the real risk situation, and the degree of their impact on the goals, results and effectiveness of organizations. Based on the principles of the process approach and the digital paradigm of risk management, the concept of optimal risk management was formulated for the first time and a technology for its implementation was proposed by optimal structural and parametric synthesis of unstructured integrated risk management system, taking into account the methods and extent of risk treatment. Optimal management is considered as a problem of optimal structural and parametric synthesis of RMS using effectiveness criteria - optimality criteria or excellence criteria, depending on the purpose and statement of the problem. The problem belongs to the class of multiextremal nonlinear programming problems with distributed variables of mixed type and functional constraints in the form of inequalities, which was solved using digital risk assessment methods developed by the author, global random search procedures and mixed-integer optimization models of block type. To assess the comparative effectiveness of risk treatment methods, a modification of the Houston model was developed according to the criterion of the value of organization, provided that the goal was achieved and resources were limited. An important difference in the Houston model modification is the cost assessment of risk in terms of the "cost of risk". The author's research and the practice of optimal design show that the use of structural and parametric optimization technology and mixed-integer optimization models of block type can lead to a significant, on average, 50-60%, increase in the RMS effectiveness. The new digital risk management paradigm is logical, reflects the result of modern digital technologies introduction in risk management practice, provides for the rejection of the hypothesis about the normal distribution of the output parameters of the ecosystem under study, and the preservation of the required information content of the "digit" in the context of process approach. The use of digital technologies and methods of optimal risk management provides the reliability of economic solutions important for practical purposes and provides new opportunities for effective management in the digital economy.

Keywords: Optimal risk management concept, process approach, integrated risk management system, optimal structural and parametric synthesis, digital method of risk assessment, risk level, cost of risk

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ТЕХНОЛОГИЯ ОПТИМАЛЬНОГО УПРАВЛЕНИЯ РИСКАМИ КАК ИНСТРУМЕНТ ОБЕСПЕЧЕНИЯ ДОСТОВЕРНОСТИ ПРИНИМАЕМЫХ РЕШЕНИЙ В ЦИФРОВОЙ ЭКОНОМИКЕ

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Современный этап развития риск-менеджмента характеризуется несоответствием внедряемых систем управления рисками реальной ситуации рисков и степени их влияния на цели, результаты и эффективность деятельности организаций. На основе принципов процессного подхода и цифровой парадигмы менеджмента риска впервые сформулирована концепция оптимального управления рисками и предложена технология ее реализации путем оптимального структурно-параметрического синтеза интегрированной системы управления рисками произвольной структуры с учетом способов и объема воздействия на риск. Оптимальное управление рассматривается как задача оптимального структурно-параметрического синтеза СУР с использованием критериев эффективности — критериев оптимальности или критериев превосходства, в зависимости от цели и постановки задачи. Задача относится к классу многоэкстремальных задач нелинейного программирования с распределенными переменными смешанного типа и функциональными ограничениями в виде неравенств. Для ее решения использованы разработанные автором цифровые методы оценки риска, процедуры глобального случайного поиска и частично целочисленные оптимизационные модели блочного типа. Для оценки сравнительной эффективности способов воздействия на риск разработана модификация модели Хаустона по критерию стоимости организации при условии достижения цели и ограниченности ресурсов. Важным отличием модификации модели Хаустона является стоимостная оценка риска по показателю «цена риска». Исследования автора и практика оптимального проектирования показывают, что использование технологии структурно-параметрической оптимизации и частично-целочисленных оптимизационных моделей блочного типа может привести к существенному, в среднем на 50–60%, повышению эффективности СУР. Новая цифровая парадигма управления рисками является закономерной, отражает результат внедрения современных цифровых технологий в практику управления рисками, предусматривает отказ от гипотезы о нормальном распределении выходных параметров исследуемой экосистемы и сохранение требуемой информативности «цифры» в условиях процессного подхода. Применение цифровых технологий и методов оптимального управления рисками обеспечивает важную для практических целей достоверность принимаемых экономических решений и открывает новые возможности для эффективного управления в цифровой экономике.

Ключевые слова: концепция оптимального управления рисками, процессный подход, интегрированная система управления рисками, оптимальный структурно-параметрический синтез, цифровой метод оценки риска, уровень риска, цена риска

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Introduction

As a result of rigorous research, the worldwide gathered experience of risk management allows decision-makers to influence the achievement of goals, justify and apply effective tools and risk treatment methods in the management of organizations, projects and business processes [1–4].

International and national ISO standards for risk management[1,2,3,4] have been developed and are constantly being improved, the current legal regulatory documents establish requirements for the development and implementation of integrated risk management systems of organization [5, 6], and existing risk management methods are increasingly used in projects and risks management [7]. The risks impact on the performance of organizations, investment projects and programs is constantly growing, and the high cost of risk often becomes the determining factor in making managerial decisions [8].

Alongside this, the modern stage of risk management development is marked by discrepancy between the implemented risk management systems and the real risk situation, and the degree of their impact on

1 ISO 31000:2018 Risk management – Guidelines

2 IEC 31010:2019 Risk management – Risk assessment techniques

3 GOST R ISO 31000-2010 Risk Management – Principles and Guidance

4 GOST R ISO/IEC 31010-2011 Risk Management – Risk assessment techniques

the goals, results and effectiveness of organizations. For a host of reasons, the risk level for entrepreneurial activity of organizations in Russia is significantly higher compared to economically developed countries [9], which causes an increase in risk tension and risk appetite for participants in entrepreneurial activity, thereby, causes the need to develop and implement integrated risk management systems (RMS).

The risk of organization is defined as a consequence of the uncertainty impact on the goals, results and effects of an organization's entrepreneurial activity, implementation of projects and business processes.

Current problems of the theory and practice of organization risk management are:

- reliability of existing standardized procedures and methods for describing, identifying and assessing risks, insufficient for practical purposes;
- poor development and implementation in risk management practice of a process approach requiring the full integration of risk management in the organization's activities, project and business process management;
- lack of standardized methods for optimal risk management and RMS synthesis under conditions of uncertainty of existing risk factors;
- insufficient skill level of persons responsible for the RMS development and implementation;
- the lack of public information about the positive results of risk management of organization;
- level of digital models and risk management methods development insufficient for the purposes of the digital economy;
- inconsistency of the RMS implemented with the real risks situation, the existing factors and the degree of their impact on the goals, results and effectiveness of organizations' activities.

The goal of research is to develop the concept of optimal risk management of organization and the technology of its implementation based on the optimal structural and parametric synthesis of RMS with distributed parameters in the digital economy format.

The digital economy means an economic activity in which key factor of production are data in digital form, processing of large volumes and use of analysis results, which, in comparison with traditional forms of managing, can significantly increase the efficiency of different types of production, technologies, equipment, storage, sale, delivery of goods and services [10–12].

The "digital economy" term was used for the first in 1995 by Nicholas Negroponte, American scientist from the University of Massachusetts, to explain the advantages of the new economy compared to the old one due to the intensive development of information and communication technologies.

According to the Digital Evolution Index 2017 research, Russia has good prospects to take a leading position in the ranking of the digital economy development. According to expert opinion, despite the relatively low overall level of digitalization, our country shows sustainable growth rates and is at the height of digital development, thereby attracting investors to the economy.

Optimal risk management concept

The results of the author's research show that the optimal risk management concept of organization can be successfully implemented only from the perspective of a systemic economy [13–16], based on a process approach, a digital paradigm and project management technology [17].

This paper proposes the technology for implementing the optimal risk management concept through optimal structural and parametric synthesis of unstructured RMS, taking into account the methods and extent of risk treatment. The problem belongs to the class of multiextremal nonlinear programming problems with distributed variables of mixed type and functional constraints in the form of inequalities, which was solved using digital risk assessment methods [18] developed by the author, global random search procedures [19] and mixed-integer optimization models of block type [20].

The effectiveness of RMS, methods of risk treatment and risk management measures is determined by the content of the RMS development process, which at each stage of development and implementation is a problem solving related either to the synthesis or analysis of RMS, without and taking into account the risk treatment (Fig. 1). Thus, synthesis and analysis act in the process of RMS development and implementation in dialectical unity.

Optimal management is considered as a problem of optimal structural and parametric synthesis of RMS using effectiveness criteria – optimality criteria or excellence criteria, depending on the purpose and statement of the problem.

The RMS development according to the completed task begins with the synthesis of the structure – generation of the original variant of the RMS, according to the results of which the parameters of the system elements are set and the transition to the analysis procedure is performed. Further, verification of compliance with established requirements, including goals, effectiveness and efficiency is performed.

If it is necessary to choose the best method of risk treatment with regard to accepted criterion, then the optimal synthesis of RMS is considered, which is based on the procedures of structural, parametric or structural and parametric optimization.

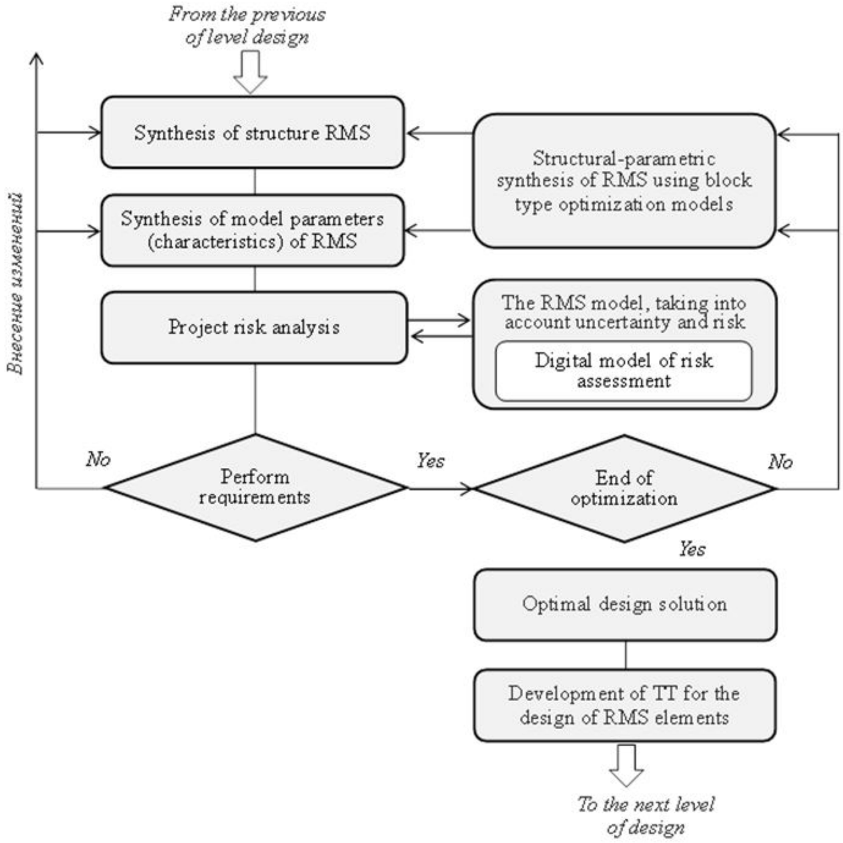

Figure 1. Development RMS

The solving of the structural and parametric optimization problem within the unified simulating algorithm is focused on obtaining optimal values of discrete parameters $X=\{x_1,\ldots,x_n\}$, which reflect the structure, and continuous parameters $Y=\{y_1,\ldots,y_m\}$, which represent the characteristics of RMSs, which are integer and real variables, respectively.

Implicitly, the statement of the problem of structural and parametric optimization based on mixed-integer optimization models of block type has the form:

$$F(X, Y) \rightarrow \min, \tag{1}$$

restrictions $$R\ (X, Y) < R^*$$

$$x_i^{min} \le x_i \le x_i^{max},\ i = 1, ..., n$$

$$y_j^{min} \le y_j \le y_j^{max},\ j = 1, ..., m,$$

where the optimality criterion (1) displays the costs for the development and implementation of an integrated risk management system, taking into account the risk treatment, as well as while providing the set conditions for implementation and the required risk level of the R* project.

A distinctive feature of problem solving is the almost simultaneous generation of values of integer and real variables, as well as the use of a special mathematical method for determining the global extremum of the objective function (1).

When generating RMS variants, the principle of variables blocking is implemented [20], according to which integer variables are combined into a block of so-called connecting variables. Depending on this block composition, values of real type variables are further generated.

Extremum of the objective function is determined by one of the global random search procedures related to the generation method. The algorithm for global random search for extremum is based on three main principles:

1) the best points from previously obtained ones are used to find new points;

2) the number of calculations of the objective function near the one of previously obtained points depends on the value of the function at this point;

3) as the point of global extremum nears, the "scope" of the search does not increase.

The author's research and the practice of optimal design show that the use of structural and parametric optimization technology and mixed-integer optimization models of block type can lead to a significant, on average, 50–60%, increase in the RMS effectiveness.

Comparative effectiveness of risk management methods

In some cases, it is advisable to use the excellence criteria in the form of inequalities to analyze the comparative effectiveness of risk treatment methods and simplifying the problem of optimal management.

The most common methods of organization's risks treatment are (Fig. 2): risk insurance; reservation of funds (self-insurance); securing a public procurement contract; formation and use of funds of the SRO compensation fund; irrevocable bank guarantee and some others.

In world practice, as a rule, either a risk insurance system or reserve funds (self-insurance) are used — in an amount necessary and sufficient to cover the expected shortfall (damage, losses). Compensation fund of self-regulatory organizations (SRO) for risk management is not formed and is not used.

Assessment of the comparative effectiveness of insurance and reservation is based on the method, which in Western literature is called the Houston method [21].

The essence of this method is to assess the impact of various risk management methods on the value of organization, which is determined through the value of the organization's free (net) assets — the difference between the value of all its assets and liabilities.

To assess the comparative effectiveness of risk treatment methods, a modification of the Houston model was developed according to the criterion of the value of organization, provided that the goal was achieved and resources were limited. An important difference in the Houston model modification is the cost assessment of risk in terms of the "cost of risk". The choice of risk management method is based on the criterion of comparative economic efficiency of insurance and reservation in the form of:

$$C_s > C_r , \quad (2)$$

where C_s — the value of organization, taking into account risk insurance;

C_r — the value of organization, taking into account the reservation.

If there is a inequality, risk insurance is more effective, otherwise, the formation and use of the reserve fund.

Despite the universality and widespread use of entrepreneurial risk management in the world practice, the Houston method has some material weaknesses. Thus, with various methods of risk management, the economic meaning of risk and its consequences is often lost, a description of risk factors is not provided, and an economic risk assessment is not performed.

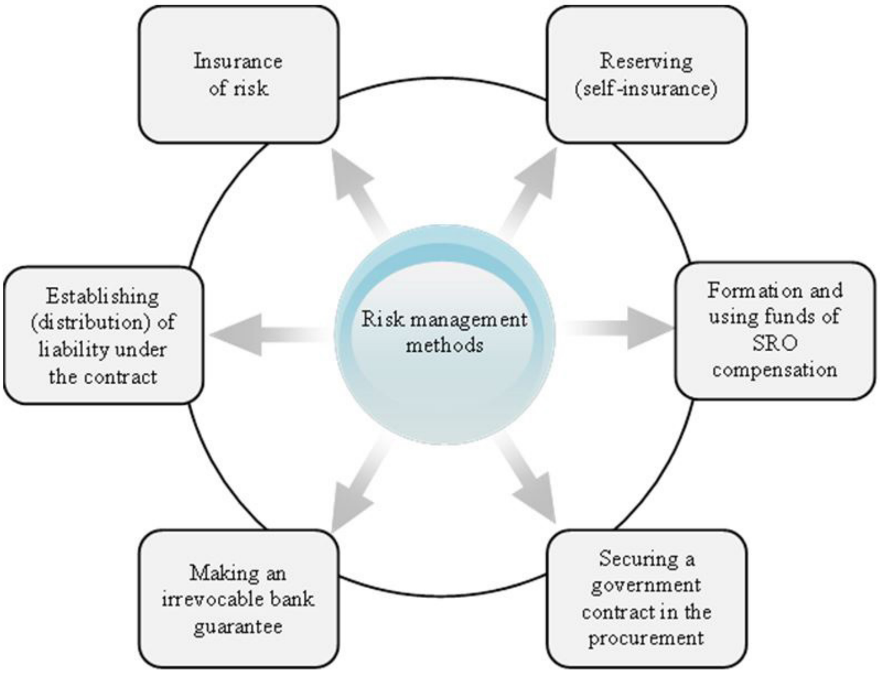

Figure 2. Risk management methods

Modification of the Houston model and its implementation in the problems of optimal risk management of organization are proposed in this paper.

Explicitly, the value of organization C_t at the end of the accounting period can be determined by modeling the costs, results and effects associated with the organization's activities, the implementation of the project or process, with discounting and inflation. Moreover, with any method of ensuring property liability and risk treatment, the value of organization C_t will be:

$$C_t = C_0 - \sum_{i=1}^{t} \alpha_i \varepsilon_i (U_i + Z_i - V_i) + d_a \sum_{i=1}^{t} \alpha_i \varepsilon_i (C_0 - U_i - Z_i + V_i) ,$$

where C_0 — the value of organization at the beginning of the accounting period without the risk treatment;

i=1,...,t is the simulation step;

α_i — the discount factor at the i-th simulation step; is determined for the constant (E) and variable (E_i) of discount rates, α_i=$(1+E)^{-m}$;

ε_i — the inflation factor; ε_i=1/G_i , where G_i is the base inflation index;

U_i — the amount of the expected shortfall (damage, losses) of the organization in case of risk materialization at the i-th step;

Z_i — costs associated with the RMS development and implementation, ensuring property liability at the i-th step;

V_i — the amount of the expected compensation for shortfall (damage, losses) in accordance with the accepted method of risk treatment at the i-th step;

d_a — the average yield of free (net) assets of the organization.

An important difference of this approach is the possibility of a cost assessment of risk of harm by indicator R — the cost of risk, taking into account the harm caused in the amount of damage U, costs Z associated with the RMS development and implementation, and possible compensation for damage in the amount of V:

$$R = U + Z - V . \tag{3}$$

Damage will be caused if the amount of actual compensation for damage (loss) is either insufficient for their full compensation or untimely in relation to the costs incurred. Obviously, this condition occurs when $R > 0$.

The functional constraints of the model are the goals and resources of the organization, the conditions and principles for the distribution of responsibility and risk, as well as the conditions for cash flows formation in the considered risk treatment methods.

Using the Houston method in an innovative setting, it becomes possible to justify the choice of the most effective method of risk treatment, as well as the fair distribution of responsibility and risk between subjects of investment activity.

Digital method of distributed risk assessment

The described procedures and the technology for optimal risk management using mixed-integer optimization models of block type for unstructured RMSs with distributed parameters are distinguished by the fact that the search for the optimal solution considers almost unlimited number of possible implementations and consequences of the uncertainty impact on the results and effects compared to the scenario method. In practice, inevitably, this leads to conclusion that the appropriateness and feasibility of applying optimal management methods directly depends on the adequacy and reliability of the distributed risk assessment methods used in the RMS analysis.

For this purpose, the Oparin-Teterin digital method of integral convolution of numerical sequences is used [17, 18], the essence of which is to obtain a discrete risk function according to the accepted indicator of the organization's activity in the form of:

$$R(\hat{E}) = P\{\hat{E}(t) < E^o\}, \qquad t \in [0, T]. \tag{4}$$

The risk function (4) characterizes the probability that the random variable E will be less than the expected value of E^0 on the planning horizon [0, T]. Probabilistically, the risk function is the distribution function of the random variable E of the RMS output parameter, taking into account the uncertainty of the existing risk factors.

As academician A.N. Kolmogorov rightly noted, "... it is reasonable to study real phenomena, avoiding the intermediate stage of their stylization in the vein of representations of mathematics as infinite and continuous, going directly to discrete models" [22].

Explicitly, the discrete risk function is determined by the vector of possible values of the effect $\{E_j\}$ and the numerical sequence $\{r_j\}$, each element of which characterizes the probability that the random variable E will be less than the expected value of E^0:

$$R(\hat{N}_{pv}) = \{r_j\} = \{a_k\}\ \{b_\tau\}, \qquad \text{где} \tag{5}$$

$$r_j = \begin{cases} \sum\limits_{\gamma=\max(1,\upsilon)}^{\min(j,\omega)} a_{j-\gamma+1}\, b_\gamma + \sum\limits_{\gamma=1}^{j-s} a_s\, b_\gamma, & \text{если } j > s; \quad (6) \\ \sum\limits_{\gamma=\max(1,\upsilon)}^{\min(j,\omega)} a_{j-\gamma+1}\, b_\gamma, & \text{если } j \le s; \quad (7) \end{cases}$$

$$j = 1,...,n;\ \ n = s + \omega - 1;\ \ \upsilon = j - s + 1.$$

The integral convolution of numbers (5) is applied (z – 1) times for z of random risk factors.

An important condition for the convolution use is the constant duration of the simulation step l_j=const, for which for all j=1, ...,n the following equality is: $E_j + E_{j+1} = E_j - E_{j+1}$.

Compared to Monte Carlo methods, this method does not require intermediate stylization of the benchmark statistics and a priori information about the desired distributions, and the necessary reliability of the assessments obtained both at the level of average values and at the tails of distributions can be achieved with a relatively small number of implementations ($10^2 - 10^3$).

The main advantage of the method of integral convolution of numbers is the ability to obtain a distributed risk assessment without and taking into account the integrated risk treatment, with set structure and known parameters of the integrated risk management system.

Conclusions

The results of research lead to the following conclusions.

The modern stage of risk management development is marked by discrepancy between the implemented risk management systems and the real risk situation, the current factors and the degree of their impact on the goals, results and effectiveness of organizations, which is due to insufficient reliability of standardized risk management procedures and economic decisions made on their basis for practical purposes.

The optimal risk management concept and the technology for implementing it discussed in this paper are directly oriented to determining the optimal or best, with regard to accepted efficiency criterion, risk treatment methods, optimal structure and parameters of RMS taking into account the uncertainty and randomness of the existing risk factors.

Using technology of structural and parametric optimization and mixed-integer optimization models of block type for practical purposes the development and implementation of RMS can lead to a significant, on average, 50-60%, increase in the RMS effectiveness.

The new digital risk management paradigm is logical, reflects the result of modern digital technologies introduction in risk management practice, provides for the rejection of the hypothesis about the normal distribution of the output parameters of the ecosystem under study, and the preservation of the required information content of the “digit” in the context of process approach.

Directions for further research

The use of digital technologies and optimal risk management methods using structural and parametric optimization procedures and mixed-integer optimization models of block type ensures the reliability of economic decisions that are extremely important for practical purposes and provides new opportunities for effective management in the digital economy.

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