Запропоновано комплексний метод управління ризиками проектів в галузі інформаційних технологій на основі комбінованого використання інтелектуальних та евристичних методів, що забезпечить підвищення ефективності проекту. Розроблено модель ризику IT проекту на основі мереж Байєса, що забезпечить визначення найбільш ймовірного сценарію ризику та розробки адекватних заходів протидії

Ключові слова: комплексний метод, управління ризиками, мережі Байєса, ймовірність, експертні методи, IT проект

Предложен комплексный метод управления рисками проектов в области информационных технологий на основе комбинированного применения интеллектуальных и эвристических методов, что позволит повысить эффективность проектов. Разработана модель риска ИТ проекта на основе сетей Байеса, что обеспечит возможность определения наиболее вероятного сценария риска и разработки адекватных мер борьбы

Ключевые слова: комплексный метод, управление рисками, сети Байеса, вероятность, экспертные методы, ИТ проект

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DEVELOPMENT OF THE COMPREHENSIVE METHOD TO MANAGE RISKS IN PROJECTS RELATED TO INFORMATION TECHNOLOGIES

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1. Introduction

Project management in the field of information technology (IT) is characterized by complexity and uncertainty. Under current conditions, instability in the external environment, as well as in the internal environment, of an IT project does not make it possible to predict future results with high accuracy. Uncertainty is related to the following parameters: objective functions of an IT project, a set of acceptable IT project implementation strategies, an IT project investment portfolio, certain forecasts (for instance, price level), cost function parameters, etc. If one does not take into consideration the uncertainty of the future when making strategic decisions, it leads to negative consequences. Underestimation of uncertainty leads to the selection of those strategies that result in the emergence of risk situations [1].

The dynamics of implementation of an IT project requires a clear definition of goals, set of actions and decisions, definitive allocation of resources, adaptation to the external environment and internal coordination, which will ensure maximum effectiveness of the project at minimal risks. In the IT project planning process, it is necessary to provide for a choice of solution at each current moment, taking into consideration changes both in the external environment and in the conditions of the implementation of an IT project. Such an approach will ensure the achievement of the set goal in future. However, in most cases, it is rather difficult to predict exactly how these changes would occur. Particularly acute is the issue of planning an IT project under conditions of rapidly growing uncertainty and risks that have a decisive impact on future results. Therefore, it is important to manage the risks of an IT project, which will reduce the over-spend of resources and losses in the project and thus will improve efficiency of the IT project. This substantiates the relevance of undertaking present research.

2. Literature review and problem statement

The uncertainty of the future is underestimated in most cases. Therefore, the use of traditional tools of forecasting and decision making, such as the analysis of discounted cash flows [2], the apparatus of statistical simulation of risk situations [3], and economic-mathematical models [4], does not yield the desired result.

The process of risk examination in various areas employs different methods. For example, when studying risks in the area of medicine, neural networks are widely used, covered in papers [5, 6]. In [7], authors propose an integrated risk assessment method for a portfolio of innovative projects based on the Monte Carlo simulation modeling. Underlying this method is the discounted cash flow model, as well as statistical studies into probabilities of the distribution of model parameters. It does not take into consideration the effect of external factors, which can lead to losses in a project. In paper [8], a dynamic risk model is investigated for a firm that invests capital in financial market assets. The proposed model is based on the investigation into a probability of bankruptcy of the firm.

When studying the risks of an IT project, author in [9] proposes a model for determining the priority of risk based on the probability indicator. This model makes it possible to quantify the risks in an IT project and rank them for the development of control measures. Paper [10] reports the investigation into probabilistic structure of an IT risk in the form of a Markov model, which allowed a detailed representation of information about all possible transitions of the state of the system over time.

Paper [11] employs the causal and situational Ishikawa diagrams and logical-probabilistic modeling when studying information identification of causative relationships under the influence of active factors on the system. In article [12], author considers a cognitive risk model for a project in the field of information technology. The proposed cognitive model reflects interrelationships between the risks of an IT project, indicates the negative or positive impact of certain risks on the remaining risks in an IT project.

Papers [13, 14] explored risks for complex technological, organizational, and technological objects and complexes based on the cognitive approach. That made it possible to establish a causal link between risk factors and risky events, as well as measures to eliminate risks.

However, the considered methods and models of risk management in IT projects do not make it possible to study the factors that may be related through unknown and non-trivial relationships and lead to a risk event. In this case, obtaining information about a risk probability and factors generating them is possible by the application of expert methods. The use of modern management methods, including intelligent, is predetermined by the complexity of managing IT projects risks. Therefore, combined application of intelligent and expert methods would make it possible to study various scenarios of risk events and the development of appropriate countermeasures.

3. The aim and objectives of the study

The aim of present study is to develop a comprehensive method for risk management of an IT project based on the combined application of intelligent and expert methods, which would make it possible to improve the efficiency of an IT project.

To accomplish the aim, the following tasks have been set:

– to formalize the process of risk management in projects related to information technologies, which would provide support to decision making under instable conditions at the existing constraints for financial and time resources;

– to construct a risk model of an IT project based on Bayesian networks, which forms the basis of a comprehensive method for risk management.

4. Methods of research into risk management in IT projects

Uncertainty is one of the central concepts in modern theory and practice of management. Managing complex objects, in particular projects related to information technology, is performed under the influence of uncertain factors. These include such factors of the external and internal environment whose values are unknown or are not known in full. Despite the lack of information, a possible impact of uncertain factors should be taken into account in the process of making managerial decisions. If this does happen, then it is possible to argue about making decisions under conditions of uncertainty. In a general case, uncertainty in decision making models should be understood as the existence of several possible outcomes of each alternative.

In [15], risk is considered to be a characteristic of the state of the system (consequences of a management decision, etc.), which operates under conditions of uncertainty, and is described by a set of events, the probability of this event and the function of losses. According to [16], risk is a situation where the outcome of a particular process is not known but its possible alternative consequences are known and there is enough information to assess the likelihood of occurrence of these consequences. That is, risk is regarded to be an event that may come with a certain probability. However, risk arises only under conditions of uncertainty. Uncertainty is the necessary and sufficient condition for risk in decision-making. One can also say that uncertainty creates a risk. Therefore, such a definition is more precise according to which risk is understood as the possibility of an unfavorable result under conditions of uncertainty [17]. Given this, it is necessary to investigate the uncertain factors causing the risk and to establish their causal relationships.

Solving a given task is impossible by applying traditional approaches based on formalized and deductive methods using the logical conclusion rules of the type "if – then". Therefore, it is necessary to apply a comprehensive combination of different methods in the management of risks in IT projects, which will allow taking into consideration existing precedents, and will be adapted to a specific situation.

The use of Bayesian networks will make it possible to analyze various factors both in the external environment and in an IT project, as well as to establish a dependence between them. The Bayesian networks ensure a dynamic account of new information as well as a comprehensive combination of expert estimates and statistical information. The basis of this method is formed by inductive justification at which hypotheses are constructed and evaluated based on experience and observations with a subsequent transition to regularities.

According to [18], a Bayesian network is a causal network, that is a network with causal connections. In the casual networks, the Bayesian classical theorem is used.

The Bayesian theorem. Let $H_1, H_2, ..., H_n$ be a pair of incompatible events and their total coincides with the entire selective space of events. Then for any random event X, which can occur only if one of the events $H_1, H_2, ..., H_n$, occurs and such that $P(X)\neq 0$, the following equalities hold:

$$p(\mathrm{H}_k \mid X) = \frac{p(X \mid H_k)\cdot p(H_k)}{\sum_{i=1}^{n} p(X \mid H_i)\cdot p(H_i)}, \quad k = 1,..,n. \qquad (1)$$

Variables that are used in the Bayesian networks can be both discrete and continuous. The character of information arrival when analyzing and making a decision may be both in real time and in the form of statistical arrays and databases. By representing the interaction between the process factors in the form of causal links, one achieves in the network the highest level of visualization and, as a consequence, a clear understanding of the essence of interaction between process factors. In contrast to fuzzy cognitive maps [19], the Bayesian networks are a promising probabilistic toolset for modeling complex hierarchical processes (static and dynamic) with uncertainties of arbitrary nature.

Probabilities $p(X|H_k)$ are set by experts *a priori*, which emphasizes the need to apply expert methods. Expert methods make it possible to obtain qualitative information in situations where the criteria of evaluation are rather new and complex, and the probability of any result cannot be calculated by statistical methods. Underlying the expert methods is the organization of work with specialists-experts and processing of expert opinions that can be expressed both quantitatively and in a qualitative form. The implementation of the expert estimation method is in rational organization of expert analysis of the problem with quantitative assessment of opinions and processing of their results. Experts act as a generator of objects (for example, external and internal risk factors) and a measure of characteristics (probability). A generalized opinion of experts is considered to be a solution to the problem. Thus, combined application of intelligent and heuristic methods will provide obtaining a synergistic effect by combining the strongest and the best sides of these methods.

5. Results of research into a comprehensive method of risk management in an IT project

First of all, for effective risk management, it is necessary to determine what kind of uncertainty generates the risk, as well as the reasons for the occurrence of a risk event. In [20], authors considered the classification of uncertainties, identified subjective and objective causes of uncertainty, which enables the study of factors that generate risk in a life cycle and in the functioning of the product of an IT project. Projects in the field of information technology are characterized by multidimensionality, complexity of structures, the presence and change of many goals, activity, non-determinism, rapidly changing external circumstances, available constraints for financial and time resources. Over a life cycle of the project, there can be a large number of events that are difficult to predict. The occurrence of these events is possible due to the impacts from various factors in the external environment and in the project. They can be investigated by different scenarios and to determine their probability. Development of adequate countermeasures will make it possible to reduce the cost of resources and losses in an IT project, which would improve the effectiveness of a project.

The Software Engineering Institute, SEI, proposed a risk management procedure [21], which includes the following steps: identification, analysis, planning countermeasures, accounting, and control. Based on this, we will build a basic IT risk management process (Fig. 1).

The methods used to analyze and measure the magnitude of risk are quantitative. However, a complete quantitative analysis is impossible in situations with a lack of statistical information about the possibility of a risk event. Therefore, it is important to establish a causal link between risk and the factors that generate it. Information about the environmental factors and the internal state of an IT project can be obtained using the expert estimation method. Therefore, a combination of intelligent and expert methods that will ensure receiving a synergistic effect and improve the quality of the results is effective. In accordance with this procedure, a comprehensive risk management method for an IT project consists of the following steps (Fig. 2).

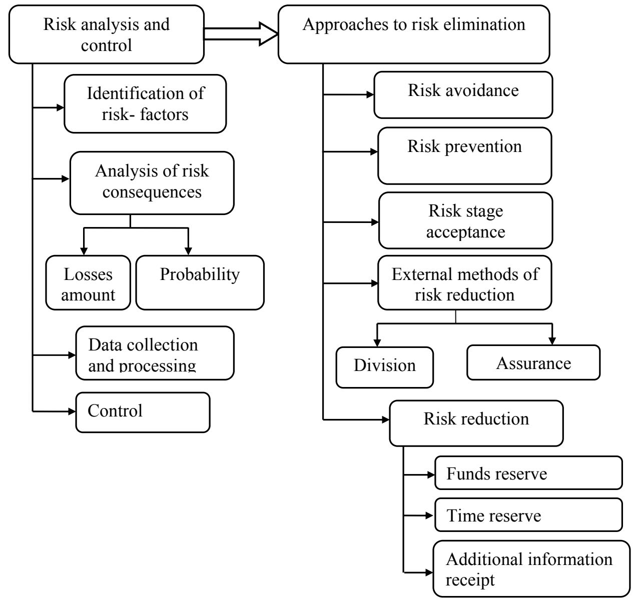

Fig. 1. Basic procedure of risk management in an IT project

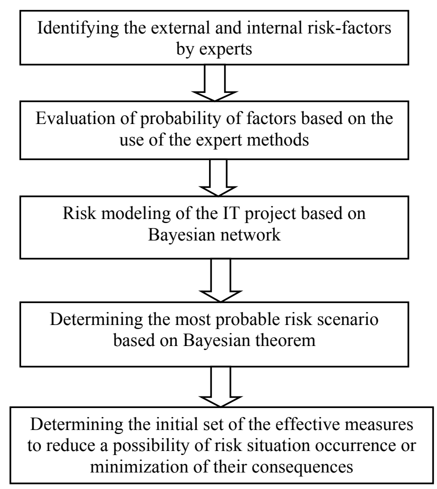

Fig. 2. Scheme of a comprehensive method of risk management in IT projects

The first and second stages of this comprehensive risk management method are implemented by interviewing the experts using the "intelligent assault" method. Specialists – members of project teams of various IT projects were engaged as experts. Experts discuss and analyze possible factors in the external environment and in an IT project that can lead to a risk event, using a universal academic example of an IT project. They also assess the probability of factors that generate risky events. The reliability of the examination is provided by a reasonable number of proposed factors, which makes it possible not to go beyond the psychological capabilities of experts. However, the obtained information depends on the competence of the experts, which is a limitation of this method.

At the third stage, the construction of the risk model of an IT project is performed based on the Bayesian networks, which is the basis of an integrated risk management method. To construct a risk model for a typical IT project based on the Bayesian networks, we determine the sample space of possible risks Ω (that is, the set of events). Then, $Risk \in \Omega$ is the risk, $fakt \in \Omega$ is the factor that generates it. By using the Bayesian formula, we will determine whether there is the risk *Risk*, provided that the factor-event *fakt* occurs, that is, we determine the probability of the risk *Risk* in the case the factor *fakt* occurs:

$$P(Risk \mid fakt) = \frac{P(Risk \cap fakt)}{P(Risk)}. \quad (2)$$

Then, the Bayesian rule, according to (1), will take the form:

$$P(Risk \mid fakt) = \frac{P(Risk \mid fakt) \cdot P(fakt)}{P(Risk)}. \quad (3)$$

Thus, the Bayesian rule (3) makes it possible to establish a cause-and-effect link between the risk and the factor that generates it. Probabilities $P(Risk \mid fakt)$ are set by experts *a priori*. In the case of obtaining additional information during the implementation of an IT project, this approach will provide clarification of the probability of risk occurrence.

Based on the main assumption about the Bayesian network construction theory (the events are exhaustive and do not intersect), we calculate the probability of occurrence of risk by formula:

$$p(Risk) = \sum_{i=1}^{n} p(Risk \cap fakt_i) = $$
$$= \sum_{i=1}^{n} p(Risk \mid fakt_i) \cdot p(fakt_i). \quad (4)$$

Substitute (4) in (3) and obtain:

$$p(Risk_k \mid fakt) = \frac{p(\text{fakt} \mid \text{Risk}_k) \cdot p(\text{Risk}_k)}{\sum_{i=1}^{n} p(Risk / fakt_i) \cdot p(fakt_i)}. \quad (5)$$

We will build a risk model for an IT project based on the Bayesian network in the form of a polytree structure. The risk $Risk_1$ is an increase in the value of the IT project generated by the following factors: $fakt_1$ – increase in the number of operations; $fakt_2$ – increase in the estimated cost of operations; $fakt_3$ – an error when choosing and making a decision in the project; $fakt_4$ – excess of resources; $fakt_5$ – increase in work duration; $fakt_6$ – developer error; $fakt_7$ – a mistake in choosing a software tool; $fakt_8$ – raising the price level; $fakt_9$ – mistake in designing the strategy and planning of the project; $fakt_{10}$ – force majeure circumstances.

In this structure of the Bayesian network of risk $Risk_1$, different types of links between the vertices are established. For example, between the vertices $fakt_{10}$, $fakt_5$ and $fakt_2$ the linear type of link is established, and between the vertices $fakt_8$, $fakt_7$ and $fakt_4$ is convergent type, between vertices $fakt_4$, $fakt_2$, $fakt_1$ – divergent. Different types of links between vertices provide an opportunity to analyze various risk scenarios $Risk_1$ – increasing the value of the IT project.

At the fourth stage, by analyzing the built Bayesian network (Fig. 3), we determine the probability of a risk occurrence $Risk_1$ – an increase in the value of the IT project by using the Bayesian theorem. For each of the vertices of the factors $fakt_6$, $fakt_8$, $fakt_9$ and $fakt_{10}$ the nominal probabilities are determined using the expert survey presented in Table 1 (T – true, F – false).

Table 1

Table of nominal probabilities of risk-factors

Vertex	Probability	
	T	F
$fakt_6$	0.36	0.64
$fakt_7$	0.21	0.79
$fakt_8$	0.42	0.58
$fakt_9$	0.4	0.6
$fakt_{10}$	0.02	0.98
$fakt_3$	0.83	0.17
$fakt_4$	0.2	0.8
$fakt_5$	0.5	0.5
$fakt_2$	0.34	0.66
$fakt_1$	0.42	0.58

By using the Bayesian formula (5), based on the values of nominal probabilities of vertices based on data from Table 1, and by using the Bayesian classical theorem, we calculate the probability of risk $Risk_1$ for different scenarios. As an example, consider the calculation of risk probability $Risk_1$ for the scenario of factors $fakt_9$, $fakt_6$, $fakt_3$, $fakt_1$ by applying a simple algorithm of direct distribution of information in the Bayesian network using the Bayesian theorem.

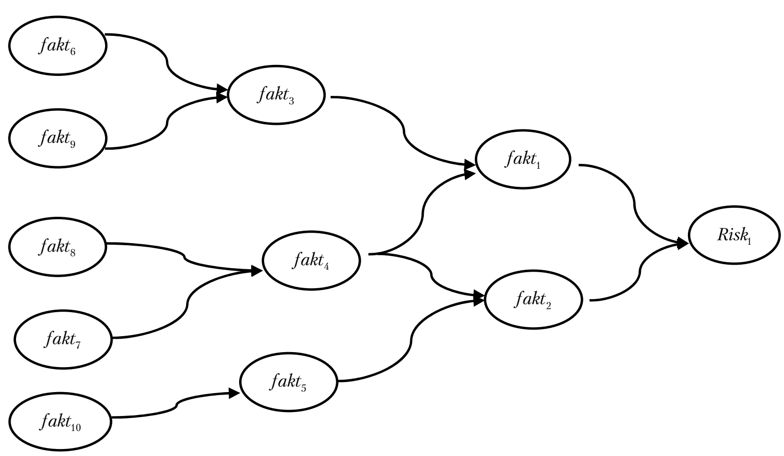

Fig. 3. The Bayesian network of risk $Risk_1$ – an increase in the IT project cost

$P(fakt_6)$	
$fakt_6$ 1	$fakt_6$ 0
0,36	0,64

$P(fakt_9)$	
$fakt_9$ 1	$fakt_9$ 0
0,4	0,6

Vertices values		$P(fakt_3 / fakt_6, fakt_9)$	
		$fakt_3$ 0	$fakt_3$ 1
$fakt_6$ 0	$fakt_9$ 0	0,83	0,17
$fakt_6$ 0	$fakt_9$ 1	0,5	0,5
$fakt_6$ 1	$fakt_9$ 0	0,5	0,5
$fakt_6$ 1	$fakt_9$ 1	0	1

Fig. 4. Fragment of the Bayesian network in the form of tables of nominal probabilities of vertices, which correspond to data from Table 1

$$P(fakt_3=0)=P(fakt_3=0\,|\,\mathrm{fakt}_6,\mathrm{fakt}_9=0)=$$
$$=\mathrm{P}(\mathrm{fakt}_3=0,\mathrm{fakt}_6=0,fakt_9=0)+$$
$$\mathrm{P}(\mathrm{fakt}_3=0,fakt_6=1,fakt_9=0)=$$
$$=P(fakt_3=0\,|\,fakt_6=0,fakt_9=0)\cdot(fakt_6=0\,|\,fakt_9=0)\times$$
$$\times P(fakt_9=0)+P(fakt_3\,|\,fakt_6=1,fakt_9=0)\cdot P(fakt_9=0)=$$
$$=0,83\cdot 0,8\cdot 1+0,5\cdot 0,2\cdot 1=0,764;$$

$$P(fakt_3=1)=P(fakt_3=1\,|\,\mathrm{fakt}_6,\mathrm{fakt}_9=0)=$$
$$=\mathrm{P}(\mathrm{fakt}_3=1,\mathrm{fakt}_6=0,fakt_9=0)+$$
$$\mathrm{P}(\mathrm{fakt}_3=1,fakt_6=1,fakt_9=0)=$$
$$=P(fakt_3=1\,|\,fakt_6=0,fakt_9=0)\cdot(fakt_6=0\,|\,fakt_9=0)\times$$
$$\times P(fakt_9=0)+P(\mathrm{fakt}_3=1\,|\,fakt_6=1,fakt_9=0)\times$$
$$\times P(fakt_9=0)\cdot\mathrm{P}(\mathrm{fakt}_6=1\,|\,fakt_9=0)\times$$
$$\times\mathrm{P}(\mathrm{fakt}_9=0)=0,17\cdot 0,8\cdot 1+0,5\cdot 0,2\cdot 1=0,236;$$

$$P(fakt_1=0)=P(fakt_1=0\,|\,\mathrm{fakt}_3=0)=$$
$$=0,764\cdot 0,42=0,32;$$

$$P(fakt_1=1)=P(fakt_1=1\,|\,\mathrm{fakt}_3=0)=$$
$$=0,236\cdot 0,58=0,137.$$

Perform similar calculations for all possible risk scenarios $Risk_1$. As a result, for different scenarios, we will obtain different values of the probability of risk occurrence $Risk_1$ – an increase in the IT project cost. Thus, we have:

– for scenario $fakt_6$, $fakt_3$, $fakt_1$ probability value $Risk_1$: $p_1=0,764$;

– for scenario $fakt_9$, $fakt_3$, $fakt_1$ probability value $Risk_1$: $p_2=0,236$;

– for scenario $fakt_8$, $fakt_4$, $fakt_1$ probability value $Risk_1$: $p_3=0,215$;

– for scenario $fakt_7$, $fakt_4$, $fakt_1$ probability value $Risk_1$: $p_4=0,096$;

– for scenario $fakt_8$, $fakt_4$, $fakt_2$ probability value $Risk_1$: $p_5=0,162$;

– for scenario $fakt_7$, $fakt_4$, $fakt_2$ probability value $Risk_1$: $p_6=0,117$;

– for scenario $fakt_{10}$, $fakt_5$, $fakt_2$ probability value $Risk_1$: $p_7=0,278$.

Based on the obtained value $Risk_1$ we can conclude that the most dangerous scenario is $fakt_6$, $fakt_3$, $fakt_1$. Under this scenario, a mistake of the developer leads to a wrong choice and decision making in the project, which causes an increase in the number of operations. Thus, the cost of the IT project increases.

At the fifth stage of the comprehensive IT risk management method, we determine the initial set of effective measures to reduce the risk of occurrence in accordance with the investigated risk scenarios and taking into consideration constraints for financial F and time T resources.

To do this, we assign a set of solutions $R=\{R_1,...,R_n\}$ to each element from the set of obtained risk probabilities $Risk_1$ $P=\{p_1,...,p_n\}$. Each solution is represented as a set $R_i=\{R_{i1},...,R_{im}\}$, where R_{ij} is the set of basic and contingency measures aimed at avoiding the risk according to factors $j=1,...,m$.

Given the constraints for financial F and time T resources, we divide set R into classes of decisions $K_1,...,K_g$, so that:

$$\bigcup_l K_l=R\,,\;K_{l1}\bigcap K_{l_2}=0, \quad (6)$$

where

$$\mathrm{l},\mathrm{l}_1,\mathrm{l}_2\in\{1,..,\mathrm{g}\},\;\;\mathrm{g}\le n,\;\;\mathrm{l}_1\ne l_2.$$

This problem has two classes of solutions:

$$K_1(\mathrm{F}\le F_0,\mathrm{T}\le T_0)\;\text{and}\;K_2(\mathrm{F}>F_0,\mathrm{T}>T_0),$$

where F_0, T_0 are the boundary values of investments and duration of the project, respectively. According to the example of scenario $fakt_6$, $fakt_3$, $fakt_1$, the set of solutions R_1 consciously satisfies the imposed constraints for resources, that is, it belongs to class K_1, and for scenario $fakt_7$, $fakt_4$, $fakt_2$ according to the resource possibilities – to class K_2.

Among classes K_1, K_2, K_1, is prevailing, which is why in accordance to the calculated probability p_1 of the risk scenario $Risk_1$, we select a set R_1 of appropriate measures to reduce the risk level. Therefore, when devising an IT project plan, special attention should be paid to the choice of a strategic alternative to the IT project, planning of resources in the IT project, as well as a thorough selection of the project team.

6. Discussion of results of research into a comprehensive method of risk management in an IT project

A comprehensive method of project risk management in the field of information technologies is designed to support management decisions under unstable conditions and makes it possible to study various risk scenarios and to establish initial response measures, taking into consideration constraints for financial and time resources. At the same time, different factors of the environment and internal state of the IT project are considered. The built risk model based on the Bayesian network makes it possible to study the cause-and-effect link between risk and its generating factors and calculate the risk probability under different scenarios. Therefore, their application enables the prediction of results of an IT project and improves performance indicators over long intervals of time.

An integrated risk management method is based on the combined application of intelligent and expert methods.

Expert methods provide information in situations where it is not possible to apply other methods, such as statistical ones. However, the application of expert methods depends on the competence of experts and methods of expert survey, which is a limitation of a given comprehensive method. Therefore, the improvement of the selection procedure and the procedure of an expert survey will further develop our study. The use of statistical methods, as an alternative to expert methods, will make it possible to obtain experimental data, but will not allow the possibility of taking into account predictive information in situations with uncertain parameters.

A comprehensive risk management method for IT projects ensures reduction in risk when making decisions in IT projects. The result of the application of this method is an increase in the effectiveness of an IT project by reducing the over-spend of resources and bringing down losses in the project. It also provides a forecast of risk events during project implementation under conditions of uncertainty with the aim of developing effective measures for risk avoidance or its minimization.

The proposed Bayesian network structure can be used as the basis for risk management information technology in an IT project and the appropriate decision support system. Information technology of risk management in an IT project will make it possible to collect, maintain, edit, process, represent and disseminate information about risks in an IT project and is the subject of further articles.

7. Conclusions

1. The process of risk management in IT projects was formalized by synthesizing expert estimation methods and intelligent data analysis that will support decision-making under unstable conditions in the presence of constraints for financial and time resources.

The proposed comprehensive risk management method was developed for a project in the field of information technology using a universal academic example. This method represents a technique for formally predicting future problems and opportunities that will ensure the implementation of an IT project over planned period. The result of applying this comprehensive risk management method is an increase in the effectiveness of an IT project by reducing project losses and over-expenditure of financial resources.

2. The constructed risk model of an IT project based on the Bayesian networks is the basis for a comprehensive risk management method. This model makes it possible to represent the cause-and-effect link between risk and the factors that generate it, as well as the calculation of risk probabilities for all possible scenarios.

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Розроблено методи перевірки правил знання-орієнтованих систем контролю, запропонована методика, яка регламентує використання методів для усунення помилок. Представлені компоненти та етапи функціонування знання-орієнтованих систем контролю, створений редактор правил і системи контролю для двох предметних областей. Аналіз результатів в системах управління навчанням показав поліпшення якості навчання і зменшення часу виконання самостійних завдань.

Ключові слова: методи перевірки правил контролю, І/АБО-граф, булеві вирази, знання-орієнтовані системи, управління навчанням

Разработаны методы проверки правил, применяемые при работе знание-ориентированных систем контроля, предложена методика, регламентирующая использование методов с целью устранения найденных ошибок. Представлены компоненты и этапы функционирования знание-ориентированных систем контроля, создан редактор правил и системы контроля для двух предметных областей. Анализ результатов в системах управления обучением показал улучшение качества обучения и уменьшение времени выполнения самостоятельных заданий.

Ключевые слова: методы проверки правил контроля, И/ИЛИ-граф, булевы выражения, знание-ориентированные системы, управление обучением

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DEVELOPMENT OF KNOWLEDGE-BASED CONTROL SYSTEMS WITH BUILT-IN FUNCTIONS OF RULES VERIFICATION AND CORRECTION

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1. Introduction

Modern monitoring and control systems are equipped, as a rule, with object parameter analyzing blocks which facilitate drawing conclusions on the emerging situations and carrying out control on this basis. It is advisable to develop knowledge-based systems for comprehensive object analysis which allows the decision maker (DM) to change the analysis rules [1]. Such systems based on facts and rules make it possible to describe states of the controlled objects and the conditions under which they arise [2].

For interactive work with control rules, special structuring of rules and such mathematical model as the AND/OR graph are used [3]. Due to the better visualization of rule presentation, this approach enables the expert to form knowledge for control systems at early stages of construction of the knowledge field.

When forming control rules, unforeseen errors may occur, so it is important to be able to find them in an automated mode. Therefore, development and improvement of methods for verification of control rules and elaboration of a procedure for their use both in searching for and elimination of errors is a focal problem.

2. Literature review and problem statement

Theory is inconsistent if there is such an assertion that both ensues from the theory and is negated by it: $T \to \phi$ and $T \to \overline{\phi}$ where T is theory and φ is assertion.

In [4], inconsistencies in the knowledge-based system are divided into external (the inconsistencies between the production system and the world model) and internal inconsistencies in the production system. The latter mean that (1)