УПРАВЛІННЯ ПРОЕКТАМИ

PROJECT MANAGEMENT

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MARKOV MODEL OF RISK IN THE LIFE SAFETY PROJECTS*

В.Д. Гогунський, Ю.С. Чернега, Е.С. Руденко. **Марківська модель ризику в проектах безпеки життєдіяльності.** Запропоновано модель для оцінки ризику в проектах і програмах у сфері безпеки життєдіяльності на основі подання оцінки у вигляді однорідного марківського ланцюга з дискретними станами і часом. Застосування запропонованої моделі дозволяє перейти від одновимірних до багатовимірних оцінок рівня безпеки організаційно-технічних систем.
Ключові слова: ризик, оцінка, система, стани, марківський ланцюг, управління проектами.

В.Д. Гогунский, Ю.С. Чернега, Е.В. Руденко. **Марковская модель риска в проектах безопасности жизнедеятельности**. Предложена модель для оценки риска в проектах и программах в сфере безопасности жизнедеятельности на основе представления оценки в виде однородной марковской цепи с дискретными состояниями и временем. Применение предложенной модели позволяет перейти от одномерных к многомерным оценкам уровня безопасности организационно-технических систем.
Ключевые слова: риск, оценка, система, состояния, марковская цепь, управление проектами.

V.D. Gogunsky, Yu.S. Chernega, E.S. Rudenko. **Markov model of risk in the life safety projects.** We propose a model to assess the risk in projects and programs in the field of safety of life through the provision of assessment in the form of a homogeneous Markov chain with discrete states and time. The application of this model allows us to go from one-dimensional to multidimensional assessment of the security of organizational and technical systems.
Keywords: risk, assessment, system, states, Markov chain, project management.

Introduction. Under the project as "a time-limited purposeful change a single system with the requirements for quality results, possible limits flow of funds and resources and a specific organization" [1]. A key part of building projects in the life safety (LS) is a goal-setting - the rationale and objectives of the project selection [2].

Formulation of the problem. This raises the problem of management of complex multi-criteria system including facilities, planned process and many of the project participants, each of which is focused on their own goals [2]. The proved choice of the objective function determines the efficiency of the projects LS [3].

Analysis of the publications. Fundamentals of Project Management using the Balanced Scorecard are proposed in [1]. The risk of reduced life under the influence of harmful factors in the working area

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of enterprises is based on the well-known Weber-Fechner law [2]. Other approaches for risk assessment developed are in [3...5]. The theoretical basis for the formation of the concept of security in the organizational and technical system is an axiom of the potential hazard, the principle of Farmer, the Weber-Fechner law, the principle of minimum Liebig, Shelford tolerance law [4]. The level of influence of environmental factors on the condition of people is based on the data in the form of “dose — effect” [6]. In general, the result of a project in LS is some product or service, which are characterized by cost and risk measure.

The purpose of the article. Development of model representations of the projects objective function in safety.

Features of the risk assessment. Management of projects and programs in LS is - a complex form of project activity in the “man — machine — environment” system.

These projects (programs) have the similar to any other project features:

— goal — the safety of operating personnel and the public;

— certain deadlines (start and end);

— established financial, material and human resources.

Differences projects LS [1]:

— the objective function of the project — a technological and environmental security — shows the desired property of a production environment or territory, and is not related to profit from the production and sale of a product or service;

— uniqueness — geographical and climatic characteristics, method of formation, mechanisms of harm and spread of harmful substances in the environment.

There are two types of governance for LS — proactive and reactive. The difference between them lies in the fact that the external action on the part of the project team in the first instance is carried out before, while the second – after the accident, which may occur as a result of accidental causes. Currently dominates the second variant, that usually triggers certain decisions to change the system to reduce the risk of adverse events in the future.

Methods for measuring and assessing risk are manifold. This is due to the fact that in different domains of life different parameters to evaluate the efficiency of objects and processes are used. Thus, while treating a patient doctor controls the “medical risk” that characterizes the success of surgery or therapy. Civil engineer manages the risk of an object under construction structural failure. Professionals in the field of occupational health and environmental safety are focused on risk assessment and management system to reduce it. They act on behalf of enterprises, customers, the community, society, or life in general. Risk is mainly assessed by the probability curve (a dimensionless value between 0 and 1), but the frequency of implementation also can be used. The frequency of implementation is — a number of cases of possible manifestations of risk during a particular period of time.

There are two long-standing views on risk: the first is based on scientific and technical assessments (the so-called theoretical risk), the second depends on the human perception of risk (the so-called effective risk). These two points of view permanently conflict in social, human and political sciences.

The theoretical risk is expressed in the form of statistics that often comes down to the probability of an undesirable event. Usually, the probability of such events, and some estimate of expected harm is combined into one plausible result, which combines a set of probabilities of risk, regret and reward in the expected value for this result.

Thus, in the statistical decision theory, risk assessment function $\delta(x)$ for the parameter θ, calculated for some of the observed parameters x, is defined as the mathematical expectation of the loss function L

$$R(\theta) = \int L(\theta, \delta(x)) \cdot f(x \mid \theta) dx, \quad (1)$$

where $L(\theta, \delta(x))$ — the loss function of the estimate θ parameter and the estimate $\delta(x)$ value; $f(x \mid \theta)$ — the probability of an undesirable event.

In practice, as a rule, use particular forms of expression (1) are used, consisting in the fact that the relationship is greatly simplified, given the specific conditions of the implementation of risk assessment. The probability of an undesired event is determined by the frequency of implementation of hazards

$$f(x\,|\,\theta) = \frac{N(t)}{Q(x)}, \quad (2)$$

where $N(t)$ — the number of adverse events during the period t; $Q(x)$ — the total number of events in the system.

Thus, the assessment of health risk when exposed to environmental factors are performed under the assumption that the level of pollution of the air or the water environment is known [6]. This means that the pollution event has already taken place: $f(x\,|\,\theta)=1$.

For the loss function $L(\theta, \delta(x))$ usually take some measure of the cost of risk units is taken, which characterizes the effects of an event. Thus, the fatal accident entails paying an employee family of five-years salary. Thus, the cost measure of risk in terms of the employer may be taken to be the size of a five-year earnings of the employee. Such a valuation can be established for other levels of severity of consequences of adverse events.

The present study proposes not to use a measure of the cost of risk, since it is an expression of the level of development of social relations, and not characteristic of the quality of organizational and technical system. To characterize the effects, you can use the value of the probability of consequences, taking into account their severity. This is a ratio of the number of adverse events (number of deaths, number of cases of disease, disability, etc.) caused by the action on the population of a particular hazard to the total possible number

$$p_i = L_i(\theta, \delta(x)) = \frac{n_i}{\sum_{i=1}^{s} n_i}, \quad (3)$$

$$\sum_{i=1}^{s} p_i = 1, \quad (4)$$

where i — condition index (events) to determine the severity of the population, i=1…s; p_i — probability state, $0<p_i<1$; n_i — the number of events of a certain severity in the population.

Under these provisions risk is the product of two variables having probabilistic nature. Further, in this study we consider the characterization of the effects of exposure to adverse environmental factors for $f(x\,|\,\theta)=1$.

Negative aspects of the factors of the “man — machine — environment” are implemented through the events that serve as indicators of their potential manifestation and contribute to the realization of potential dangers in the future. On the recommendation of the International Organization of Health different levels of damage and, therefore, the probability of impact can be determined by the structure of events: D_1 — norm; D_2 — minor violations; D_3 — indirect evidence; D_4 — denial; D_5 — accident

Represented as a graph of transitions from one state D_i to another D_j, which denote the probabilities $\pi_{ij}\{i=\overline{1,5};\, j=\overline{1,5};\, i \neq j\}$ of transitions to other states, as well as the probability $\pi_{ij}\{i=\overline{1,5};\, j=\overline{1,5};\, i = j\}$ of saving the current state (Fig. 1). These transitional probabilities can be determined by expert methods. The resulting homogeneous Markov chain with discrete states and the time can be solved by well-known methods [3].

Additionally, compared to the pyramids recommended by the Health International society, on a graph marked switch to less dangerous levels of damage in one, two or even three levels, which may take place in case of organizational, preventive or therapeutic measures.

We describe a homogeneous Markov chain with discrete states and discrete time steps and changes calculated using the probabilities of the states. [4] Under the steps we understand some complex-effects of measures implemented by an object that changes the parameters D_i.

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Suppose that at any time t (after any k-th step) index **D** can be in one of the states: $\mathbf{D}=\{D_1, D_2, \dots D_5\}$, that is, to make one of the full group of incompatible events: $D_1^{(k)}, D_2^{(k)}, \dots, D_5^{(k)}$. The indicator **D** may vary at each step k

$$\mathbf{D}=\{p_1(k), p_2(k), \dots, p_5(k)\}.$$

Denote the probability of finding an object in the states j: $j=\overline{1,n}$ in the completion of steps k

$$k=1;\ p_1(1)=P(D_1^{(1)});\ p_2(1)=P(D_2^{(1)});\ \dots,\ p_5(1)=P(D_5^{(1)}).$$

$$k=2;\ p_1(2)=P(D_1^{(2)});\ p_2(2)=P(D_2^{(2)});\ \dots,\ p_5(2)=P(D_5^{(2)});$$

$$\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots$$

$$k=l;\ p_1(l)=P(D_1^{(l)});\ p_2(l)=P(D_2^{(l)});\ \dots,\ p_5(l)=P(D_5^{(l)}).$$

Probabilities $p_1(k)$, $p_2(k)$, …, $p_5(k)$ are the probability of the state of a homogeneous Markov chain, in which the transition probabilities are independent of the step. Considering the property of incompatible actions, forming a complete set for each step k

$$p_1(k)+p_2(k)+\dots+p_5(k)=1.$$

The transition probabilities π_{ik} $\{i=1\dots n;\ k=1\dots n;\ n=5\}$ can be obtained by expert methods. “A delay” π_{ii}, complement to one the sum of the transition probabilities of transition to other states.

Based on the matrix of transition probabilities, provided that the initial state of the system is known, it is possible to find the state probabilities $p_1(k)$, $p_2(k)$, …$p_5(k)$ after each k-th step of management actions on the system. The equations for calculating the probabilities of the form:

$$\begin{aligned}
p_1(k+1)&=p_1(k)\cdot\pi_{1.1}+p_2(k)\cdot\pi_{2.1}+p_3(k)\cdot\pi_{3.1}+p_4(k)\cdot\pi_{4.1}+p_5(k)\cdot\pi_{5.1},\\
p_2(k+1)&=p_1(k)\cdot\pi_{1.2}+p_2(k)\cdot\pi_{2.2}+p_3(k)\cdot\pi_{3.2}+p_4(k)\cdot\pi_{4.2}+p_5(k)\cdot\pi_{5.2},\\
p_3(k+1)&=p_1(k)\cdot\pi_{1.3}+p_2(k)\cdot\pi_{2.3}+p_3(k)\cdot\pi_{3.3}+p_4(k)\cdot\pi_{4.3}+p_5(k)\cdot\pi_{5.3},\\
p_4(k+1)&=p_1(k)\cdot\pi_{1.4}+p_2(k)\cdot\pi_{2.4}+p_3(k)\cdot\pi_{3.4}+p_4(k)\cdot\pi_{4.4}+p_5(k)\cdot\pi_{5.4},\\
p_5(k+1)&=p_1(k)\cdot\pi_{1.5}+p_2(k)\cdot\pi_{2.5}+p_3(k)\cdot\pi_{3.5}+p_4(k)\cdot\pi_{4.5}+p_5(k)\cdot\pi_{5.5}.
\end{aligned} \tag{5}$$

The system (5) has 10 variables — transition probabilities π_{ij} are known. Five equations include 10 unknown variables. Solving this system requires the number of equations to be equal to the number of unknown variables, ie five ties must be added, based on the initial conditions. Usually the state probabilities $p_i(k)$, $i=1\dots5$ are set as known variables.

Behavior of the system is determined by the initial state $\{p_1(0), p_2(0), \dots p_5(0)\}$ and the transition matrix, which, for each new project has different values of its elements:

$$\left\|\pi_{ij}\right\|=\begin{Vmatrix}\pi_{1,1} & \pi_{1,2} & 0 & 0 & 0\\ \pi_{2,1} & \pi_{2,2} & \pi_{2,3} & 0 & 0\\ \pi_{3,1} & \pi_{3,2} & \pi_{3,3} & \pi_{3,4} & 0\\ \pi_{4,1} & \pi_{4,2} & \pi_{4,3} & \pi_{4,4} & \pi_{4,5}\\ 0 & 0 & 0 & \pi_{5,4} & \pi_{5,5}\end{Vmatrix}=\begin{Vmatrix}0,75 & 0,25 & 0 & 0 & 0\\ 0,15 & 0,75 & 0,10 & 0 & 0\\ 0,05 & 0,15 & 0,65 & 0,15 & 0\\ 0,02 & 0,05 & 0,15 & 0,63 & 0,15\\ 0 & 0 & 0 & 0,25 & 0,75\end{Vmatrix}.$$

Simulation results example using a Markov chain shows the possibility of a multi-dimensional assessment of the probability of occurrence of certain events (Fig. 2).

The system can be changed by the influence of perfomers. This is possible by using, for example, health and safety law, socio-economic, organizational, technical, sanitary and preventive measures aimed at protecting the health and efficiency of employees [4]. It is necessary to ensure the proper management of projects in LS. After all the project can go into the category of “bad” and not complete at all if any errors or project team improper actions take place [5].

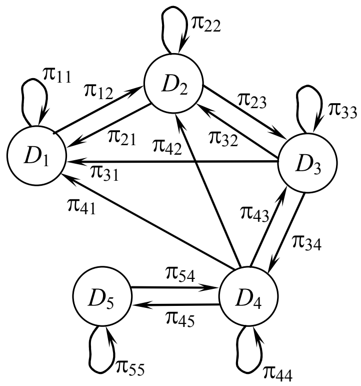

Fig. 1. A labeled graph of the system: D_i — the discrete states; π_{ij} — transition probabilities

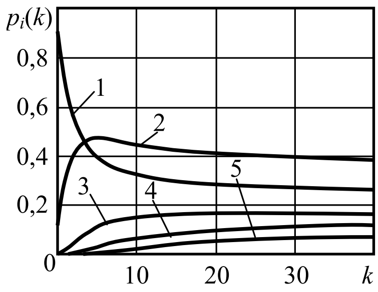

Fig. 2. Changing the state probabilities of the system during the work projects: pi(k) — the probability of state, i=1…5, k — step number — the discrete time

Conclusions. The proposed model reflects the Markov processes in LS. System structure and topology of relationships allow to draw preliminary conclusions about the concept of proactive systems management LS — do not expect serious consequences and accidents. You must use the indicators of levels of damage occurrence and form events, and introduce new methods for preparation and healthy life.

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ЭКОЛОГИЧЕСКАЯ ОЦЕНКА ПРОЕКТОВ

Т.М. Олех, К.В. Колесникова, С.В. Руденко. **Екологічна оцінка проектів**. Запропоновано підхід до виявлення екологічних проблем на ранніх стадіях розгляду проектів для включення в них заходів, спрямованих на поліпшення якості навколишнього середовища та запобігання, зменшення та компенсацію екологічного збитку. Розглянуто оцінку якості екологічної складової проекту.
Ключевые слова: проекти, екологічні характеристики, вплив на навколишнє середовище, якість екологічної оцінки.

Т.М. Олех, Е.В. Колесникова, С.В. Руденко. **Экологическая оценка проектов**. Предложен подход к выявлению экологических проблем на ранних стадиях рассмотрения проектов для включения в них мероприятий, направленных на улучшение качества окружающей среды и предотвращение, уменьшение и компенсацию экологического ущерба. Рассмотрена оценка качества экологической составляющей проекта.
Ключові слова: проекты, экологические характеристики, влияние на окружающую среду, качество экологической оценки.

T.M. Olekh, K.V. Kolesnikova, S.V. Rudenko. **Environmental assessment of projects.** An approach to the identification of environmental problems at the early stages of the projects to be included in the draft of measures aimed at improving the quality of the environment and the prevention, reduction and compensation for environmental damage. The evaluation of the quality of environmental component of the project is considered.
Keywords: projects, environmental performance, the impact on the environment, the quality of environmental assessment.

Введение. Цель экологической оценки (ЭО) состоит в обеспечении качества проектирования, чтобы проекты, планы развития, программы и др. были приемлемы с точки зрения окружающей среды и устойчивости. ЭО используется для прогноза, анализа и интерпретации значимых воздействий