

Risk management system model for construction projects

Boris Titarenko¹, Amir Hasnaoui² and Roman Titarenko³

¹ Moscow State University of Civil Engineering, Yaroslavskoe shosse, 26, Moscow, 129337, Russia

² The Finance and Economics Department, La Rochelle Business School, France

³ Stockholm School of Economics, Sweden/Russia

E-mail: boristitarenko@mail.ru

Abstract. This paper shows a project risk management system model allowing to better identify risks and to manage them throughout the life cycle of the project. It shows the most popular methods of risk probability assessment and tries to indicate the advantages of the robust approach over the traditional methods. Modern development of project management as well as the accumulated knowledge and experience in this field made it possible to integrate project management knowledge into a single system model. Within the framework of this model standard and robust approaches are applied and expanded for the tasks of project data analysis. The suggested algorithms used to assess the parameters in statistical models allow to obtain reliable estimates.

1. Introduction

One of the project risk management processes is a quantitative analysis of risks. The quantitative analysis usually includes the assessment of the potential impact of project risks and their probabilities. If to solve the first problem, it is sufficient to attract a qualified specialist in this field and provide him or her with necessary statistical information and tools to estimate the potential damage from the risk occurrence, then to estimate the probability of risks it's necessary to apply more sophisticated and specialized methods.

This paper shows the most popular methods of risk probability assessment and tries to indicate the advantages of the robust approach over the traditional methods.

The main problem at the conceptual stage of project management is the selection of approaches and methods that will be used in project risk management. To this end, probabilistic and statistical methods are used more often in practice [1, 2]. In the case when these distribution laws are far from normal (Gaussian), the application of standard methods can lead to a substantial distortion of the results as was shown by Tukey. He showed that even at small deviations of the model from Gaussian, the traditional estimates quickly lose their optimal features.

In 1960s the robust methods were developed which allow to find stable estimates in situations of inhomogeneous populations [3].

At the end of the 20th century, it was first suggested to use the robust methods for project risk management [4]. In recent years, studies in this field have been continued [5, 6, 7]. The purpose of



this paper is to develop a system model of project risk management and to form on its basis such approaches that combine the traditional methods of project risk analysis with the robust methods to ensure stable estimates of risk parameters.

This paper has the following structure. Section 2 examines the issues of project risk management, characterizes the project management system model developed by the Russian Project Management Association SOVNET and formulates the project risk management system model. Section 3 considers the traditional risk management tools, including probabilistic and statistical methods of risk analysis. Section 4 applies the robust approach for the tasks of project data analysis, shows theoretical problems of the robust models. Section 5 concludes the paper.

2. Project risk management system model

Risk management is defined as the methods of determining, analysis, assessing, preventing, adoption of measures to reduce risk throughout a project life cycle and distribute the potential damage from a risk among all project participants [8].

Modern development of project management as well as the accumulated knowledge and experience in this field made it possible to integrate project management knowledge into a single system model. It was developed by the Russian Project Management Association SOVNET and then tested in theory and practice of project management in Russia [2]. The project management system model includes three main blocks: management object, management subjects and management processes that continuously interact with each other.

Within the framework of the model and on the basis of previously formulated methodological approaches to systemize project risk management it is possible to suggest creating the *project risk management system* model including the following principal provisions.

2.1. Management objects

Applying this structure to project risk management, it's obvious that management objects are various risks involved in any project implementation. Such risks arise due to the fact that any project or any activity is carried out in the situations of great uncertainty. Clearly defining the concept of risk and using the appropriate tools, risk management methods allow to manage efficient and secure in the situations of uncertainty.

Project risk is characterized by three parameters [9]:

1. *Risk event* as a random event that disrupts the normal project implementation and causes the deadlines extension of work, its costs, its low quality and other adverse consequences.

2. *Probability* of a risk event occurrence that reflects the objective possibility of a risk event occurrence.

3. *Damage* from a risk event occurrence that characterizes the losses from a risk event occurrence.

Risk danger is a product probability of a risk event occurrence on the expected damage from it. The concept of risk danger allows to rank risks according to their degree of importance for a successful implementation of a project.

Risk situations are generated by project environment and therefore its risks are divided into external and internal. Internal risks are the results of internal project activities such as design, technical, technological, organizational, financial, etc. External risks appear as the results of the external environment activities such as natural, political, social, economic, etc. To manage risks means to adopt measures to reduce them. This can be done either by reducing the probability of any risk event occurrence or by reducing damages from it. Reduction of the likelihood and potential damage are achieved by different design solutions. In terms of management more "manageable" risks are internal and less ones are external risks.

Proper risk management is preceded by the procedure of risk analysis. It consists of two stages: risk identification and quantitative risk assessment.

At risk identification stage the risks sources and any possible risk situations are defined, a list of risks is made and polling of experts is carried out. At the stage of quantitative risk assessment the like-

likelihood of risk events occurrence is evaluated, the likelihood of costs from possible damage is assessed and if necessary, the simulation is run, and expert evaluations are processed.

The result of risk analysis is ranked according to the danger of a risk register that serves as the starting point of compiling a Risk Management Plan. Risk management is carried out in accordance with the Risk Management Plan within the framework of the developed monitoring system for the prompt adjustment of the Plan during project implementation.

2.2. Management subjects

Risk management can be carried out at the following levels:

1. Corporate level (management of the functional units and programs). This level of risk management involves tracking of the basic parameters in projects and programs such as time, cost, quality, impact of risk factors on them and forecasting of the results adopted by the strategic decisions.
2. Level of any project management or project-oriented activities of management is directly related to the preparation of a risk management plan, its implementation and control.
3. Level of operational management where risk management is carried out using the system of identification and monitoring of risks developed at the second level of management.

2.3. Management processes

Risk management processes consist of the following stages:

1. Risk management concept, at this stage risk management strategy is developed and requirements to the risk management system are formulated.
2. Risk response planning, where a risk analysis is conducted, including the identification of risks, assessment of their probability and damage, risk ranking and making a Risk Management Plan.
3. Organization and monitoring of risk responses. Here the procedures of risk management are described, responsibility for risk management is allocated and the implementation of risk responses is monitored.
4. Analysis of the condition and adjustment of risk mitigation measures. At this stage the analysis of the implementation of a risk management plan is carried out, corrective actions are developed and decisions on response to occurred risk events are taken.
5. Completion of risk management. This step includes the analysis of a risk management plan implementation and of the use of reserves, synthesis of actual data on risk manifestation, building an archive and a final risk management report.

Risk management as one of the functions of project management is integrative, i.e. it uses almost all functions of management such as time, cost, quality, contracts and communications.

The most dangerous risks become neutral at the initial stage due to the preventive measures, others are allocated between the project participants, and still others are insured and the rest are the subject to adjustment procedure: decisions on the change in the project field area, budget, schedule, delivery schedule, contracts are taken, i.e. capabilities of the basic functions of project management are realized.

3. Risk management tools

To implement the reviewed project risk management model in Section 2 it's necessary to have special tools, allowing to make a reliable analysis of risk events in the project, to assess their probability of occurrences and risks, to make predictions about the project development, to assess possible consequences of project management decisions. For this purpose are used probabilistic and statistical methods.

3.1. Probabilistic methods

The main tool for calculating probabilities of risk events is the probability theory. The probability theory suggests and examines a variety of probabilistic situation models. Random events and random values are the objects of the probability theory. In case of a random value, its behavior is fully de-

scribed by a probability distribution law, i.e. for discrete random variable $P(x_1), \dots, P(x_n)$ or a probability density function $f(x)$ for continuous random variables.

In assessing probability of risk events, it's necessary to first analyze risk situation and determine the possibility of using known models.

The most common is the model of normal (Gaussian) distribution. Its widespread use is due to the central limit theorem. In practice many of random variables are formed under the influence of a large number of factors, the impact of each is insignificant. Then, if their effect is linear (i.e. they are summed), the resulting random variable has a normal distribution. Beta distribution is used in building practice to describe the duration of many works. In reliability theory to describe the lifetime of devices and their reliability a number of distributions are used such as exponential, Poisson, Erlang and etc. Log-normal and gamma distributions are often used as the models of income distribution and can be applied in the financial analysis of the project. Rectangular distribution is implemented in computers as a random number generator and is used in simulation.

All the above distributions may be used to some extent in the project risks analysis.

3.2. Statistical methods

3.2.1. Estimation of models parameters

Once a suitable probabilistic model is chosen, there is the question of the parameters values that characterized it.

For example, if it is the model of Gaussian distribution, it is necessary to know its parameters m and σ^2 , if it is an exponential distribution – the value α and etc. As a rule, the values of these parameters are unknown and they should be assessed. There are different assessment methods.

Statistical methods are the collections of data on the reviewed model and their processing by the mathematical statistics methods. The most common estimation method in mathematical statistics is the maximum likelihood method [10].

3.2.2. Maximum likelihood method

If a random variable X has a probability density function $p(x, \theta)$, estimation of $\hat{\theta}$ by the maximum likelihood method is defined as the solution of an extreme task:

$$L(\theta, x_1, \dots, x_n) = \prod_{i=1}^n p(x_i, \theta) \Rightarrow \max_{\theta}, \quad (1)$$

x_1, \dots, x_n – n observations of random variable X .

3.2.3. Methods of correlation analysis

Studying random factors affecting the project as a whole and its parts, they are usually considered as independent random variables. However, some factors are often linked and therefore their joint effect on the project depends on the nature and their level of correlation. To study the dependence of random variables it is possible to apply the methods of correlation and regression analysis.

Characteristic of the relation between random variables in the probability theory is the correlation coefficient.

The correlation coefficient ρ shows the relation degree between the random variables X and Y and is defined by

$$\rho = \frac{E(X - E(X))(Y - E(Y))}{\sqrt{VAR(X) \times VAR(Y)}}, \quad (2)$$

where $E(X)$ and $VAR(X)$ are the mathematical expectation and variance.

As defined $|\rho| \leq 1$. For independent random variables it is equal to 0. By definition, the value of the correlation coefficient in the interval is $-1 \leq \rho \leq 1$. The values -1 and 1 correspond to the cases of full linear dependence. It should be noted that the correlation analysis can be used only to define the degree of linear dependence between random variables.

To estimate the correlation coefficient between the random variables X and Y , it is necessary to observe them and calculate the sample correlation coefficient $\hat{\rho}$. Since the value $\hat{\rho}$ is calculated on a limited sample, it has a significant variance. Thus in the situation of low $\hat{\rho}$ value begs the question: is true ρ in fact not equal to zero, i.e. is there a correlation between X and Y or is it possible to explain deviation of $\hat{\rho}$ from zero by the random nature and limited sample?

The answer to this question can be given using a hypotheses testing. Assume that true ρ is equal to 0 then

$$T = \frac{\hat{\rho}\sqrt{n-2}}{\sqrt{1-\hat{\rho}^2}} \quad (3)$$

has Student's t -distribution.

Comparing value T with the critical value t_{cr} taken from the table of Student's t -distribution, it's possible to set the value $\hat{\rho}$.

If $|T| > t_{cr}$, the null hypothesis is rejected and $\hat{\rho}$ is considered to be significative, i.e. the true ρ value is different from zero.

3.2.4. Regression analysis method

Regression analysis of the random variables is carried out after the methods of correlation analysis establish the presence of relations between them. The regression defines a functional dependence of one average random variable on the value of another random variable. The structure of this function depends on the law of joint distribution of random variables and can be quite complicated. Therefore, in practice, it's often restricted by the linear dependence – it is easier to calculate, and in case of joint normal distribution of random variables it is theoretically linear.

The linear regression calculation is carried out by formula which uses the observations of the random variables X and Y

$$r(x) = \bar{y} + \hat{\rho} \frac{\hat{\sigma}_y}{\hat{\sigma}_x} (x - \bar{x}) \quad (4)$$

$$\bar{x} = \frac{1}{n} \sum_{i=1}^n x_i, \quad \bar{y} = \frac{1}{n} \sum_{i=1}^n y_i, \quad (5)$$

$$\sigma_x^2 = \frac{1}{n-1} \sum_{i=1}^n (x_i - \bar{x})^2, \quad \sigma_y^2 = \frac{1}{n-1} \sum_{i=1}^n (y_i - \bar{y})^2. \quad (6)$$

3.2.5. Robust methods

The traditional methods of the project risk estimation in mathematical statistics are based on the precise knowledge of the models of the random variable distribution. The main approach is the maximum-likelihood estimation which defines the best estimations for each probability distribution. However, this approach has one significant drawback, namely that the resulting estimates are not resistant to the possible variations from the assumed distribution model. The distributions observed in the real life only slightly correspond to the theoretical models. Hence, the models based on the traditional methods in these conditions frequently lose their usefulness.

Robust methods are based on the estimates that may not be optimal, but they are resistant to the possible variations [3] from the assumed distribution models. These estimates are called robust estimates. The procedures of robust estimation are rather laborious.

Currently the robust methods cover the following range of tasks: regression and correlation analysis, dispersion analysis, factor analysis, planning of experiments, simulation, statistical estimation of models parameters, estimation of systems reliability.

On the basis of the analysis it seems appropriate to offer the following ways of application of the robust methodology to be able to combine the traditional methods of project risk analysis with the robust methods to ensure stable estimates of risk parameters.

1. Development of the specific robust methods focused on the specific tasks and the creation of the appropriate mathematical software.
2. Application of the prepared sets of the robust programs with their appropriate adaptation to the specific tasks.
3. "Robustification" of the available mathematical software to create robust procedures

4. Discussion

In this paper on the basis of the SOVNET project management system model the project risk management system model was developed allowing to determine, analyze, assess, prevent and adopt measures to reduce risk throughout a project life cycle as well as to distribute the potential damage from a risk among all project participants. This model is implemented on different levels: corporate, project and operational, which allows to use the tools of risk management in situations of uncertainty effectively.

Developing the model it was assumed that the risk management is one of the functions of the project management and it is integrative in nature, i.e. it uses almost all management functions. So, the risks can be neutralized in the initial stage, can be distributed among the participants of the project, can be insured, can be taken decisions to change the project field area, schedule, budget, etc.

The most dangerous risks are neutralized at the initial stage due to the preventive measures, others are allocated between the project participants, and still others are insured and the rest are the subject to adjustment procedure: decisions are taken on the change in the project field area, budget, schedule, delivery schedule, contracts – i.e. capabilities of the basic functions of project management are realized.

In addition, the paper shows the main traditional risk analysis methods: probabilistic and statistical, and it also suggests the application of the robust approach to the tasks of statistical data processing during a project risks analysis.

Thus, this paper shows that the optimal solutions largely depend on the methods of information processing on which basis these solutions are taken. Reliability of the solutions can be reached through the use of special robust procedures for the analysis of management information. An adequate model and a robust information technology decision-making represent the necessary and sufficient conditions for effective management.

References

- [1] Voropaev V, Barkalov , Burkov V, Sekletova, G, 2005. Mathematical foundations of project management. Higher School, Moscow.
- [2] Voropaev V, Mironova L, Polkovnikov A, Sekletova G, Tovb A, Tsipes G, 2014. National Competence Baseline, NCB, version 3.1. SOVNET, Moscow.
- [3] Huber P, Ronchetti E, 2009. *Robust statistics*, second ed. J. Wiley, New Jersey.
- [4] Titarenko B, 1997. Robust technology in risk management. *International Journal of Project management* **15**(1).
- [5] Titarenko B, Titov S, Titarenko R, 2014. Risk management in innovation projects. *Applied Mechanics and Materials* **638–640**, 2338–2341.

- [6] Bubnov G, Titarenko B, Titov S, Titarenko R, 2015. Isorisk curves as a tool for increasing flexibility of risk management in engineering projects. *Contemporary Engineering Sciences* **8(21)**, 991–999.
- [7] Volkov A, Sedov, A, Chelyshkov P, Titarenko B, Malyha G, Krylov E, 2016. The theory of probabilities methods in the scenario simulation of buildings and construction operation. *Research Journal of Pharmaceutical, Biological and Chemical Sciences* **7(3)**, 2416–2420.
- [8] Caupin G, Knoepfel H, Koch G, Pannenbacker K, Perez-Polo F, Seabury C, 2006. *ICB IPMA Competence Baseline, version 3.0*. IPMA, the Netherlands.
- [9] PMI, 2013. A guide to the Project Management Body of Knowledge (PMBOK Guide), fifth ed. PMI, USA.