Risk assessment for construction projects of transport infrastructure objects

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Abstract. The paper analyzes and compares different methods of risk assessment for construction projects of transport objects. The management of such type of projects demands application of special probabilistic methods due to large level of uncertainty of their implementation. Risk management in the projects requires the use of probabilistic and statistical methods. The aim of the work is to develop a methodology for using traditional methods in combination with robust methods that allow obtaining reliable risk assessments in projects. The robust approach is based on the principle of maximum likelihood and in assessing the risk allows the researcher to obtain reliable results in situations of great uncertainty. The application of robust procedures allows to carry out a quantitative assessment of the main risk indicators of projects when solving the tasks of managing innovation-investment projects. Calculation of damage from the onset of a risky event is possible by any competent specialist. And an assessment of the probability of occurrence of a risky event requires the involvement of special probabilistic methods based on the proposed robust approaches. Practice shows the effectiveness and reliability of results. The methodology developed in the article can be used to create information technologies and their application in automated control systems for complex projects.

1. Introduction

One of the project risk management processes is a quantitative analysis of risks. Usually the quantitative analysis includes the assessment of the potential impact of project risks and of their probabilities. The first task is relatively easier and can be performed by the specially trained analyst with the help of the statistical data and model of potential damage appraisal. However, the probability assessment needs more complicated specialized methods. The article reviews the most popular methods of risk probability assessment and tries to show the advantages of the robust approach over the more 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. As a rule, these are probabilistic and statistical methods, imitation and expert methods. [1] These traditional methods are usually based on explicit or implicit assumptions about the normality of the distribution laws of the indicators considered. [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 obtained. [3] In the 60s of the last century the robust methods were developed which allow finding stable estimates in situations of...
inhomogeneous populations [4,5]. At the end of the 20th century, it was first proposed to use robust methods for risk management in projects [6]. In recent years, studies in this field have been continued [7-10]. The aim of the work is to develop a methodology for applying traditional methods in combination with robust methods that allow obtaining reliable risk assessments in projects.

2. Methodological Framework

2.1 Probabilistic methods

The most widespread method of the risk probability assessment is based on the model of Gaussian distribution. The popularity of this model is connected with the fact that it is based on the central limit theorem. Many random variables in the practice are influenced by the big number of various factors, each of which has an insignificant influence. If the impact of these factors has a linear nature (in other words the total impact of the factors is summarized), the resulting random variable has the normal distribution.

In the practice of project management, especially in construction, risk managers use the models based on beta-distribution. In reliability theory to describe the operating period of different appliances engineers use models based on exponential, Poisson, Erlang and other distributions. In feasibility studies of capital projects the logarithmic normal and gamma distributions are sometimes used. Uniform distribution is used in different software applications to create the random generators and can be applied in simulation models. All types of distributions can be used in quantitative and qualitative risk analysis. It is known or postulated that if a relevant variable has a normal distribution, the task of probability distribution assessment reduces to the definition of two parameters – mean value and dispersion. These two parameters can be evaluated by experts or calculated with the help of the known formulas from mathematical statistics.

For the purposes of project scheduling the duration of project tasks can be also calculated on the basis of the existing norms and available human resources. In practice, however, the duration calculated in this way corresponds to the factual numbers only at a small extent. The specific nature of many project tasks, especially in the field of construction, leads to limit the duration of tasks by the issues connected with technology and by common sense. The duration calculated with norms and standards usually corresponds to the most expected value of duration. Many researchers have shown that the probability distribution of project task durations can be described with high level of accuracy as beta-distribution with parameters \(a, \ b, \ m\), where \(a\) – minimal value of the task duration, \(b\) – maximal value, \(m\) – the most expected value.

2.2 Scenario methods

These methods are based on the development of different scenarios that describe the potential project realization in its basic and the worst possible alternatives. Each scenario reflects the political, economic and legal context of the project, the possible project cash flows, the indices of effectiveness and efficiency, potential project results for key stakeholders of the project.

Each scenario must have:
- the set of the initial variables and inputs,
- the set of calculated values of resulting indices,
- the probability of the scenario defined by experts.

The project can be considered as an effective one if in each scenario the interests of all stakeholders would be achieved and possible negative consequences could be eliminated within the limits of the available reserves or compensated by insurance payments.

2.3 Statistical methods

These methods are based on processing quantitative data from observations over risk events for the purposes of calculating main statistical parameters – mean value, dispersion, probabilistic distribution
etc. Statistical methods need the prior collection of data on analogous projects and/or execution of the relevant experiments. If the information about the finished projects and experiments is available, there is the possibility to define the functions of distribution of the random variables, the functions of regression and correlation.

The most popular method of evaluation in mathematical statistics is the method of maximum-likelihood estimation (MLE). If a random variable $X$ has the density of distribution $p(x, \theta)$, then the value of $\hat{\theta}$ can be calculated as the solution of the extreme problem:

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

where $x_i$ – observations over the variable $X$.

### 2.4 Expert methods

These methods are used to assess unique risk events in projects. The experts give their estimates which are processed with the methods of mathematical statistics.

The experts should work with the specially developed questionnaires where they need to provide the estimates of risk events probability. The results can be processed with the traditional statistical methods or robust methods. The expert estimation frequently lead to the problem of the averaging the opinions of experts. To avoid this problem there is the method of weighed estimations which implies that every expert should have the particular weight that reflects the competence of this expert. Delphi technique can also be used to mitigate the problem of averaging. Delphi technique is based on the interactive procedures of evaluation with correction of the estimates after each iteration.

### 2.5 Insurance risks

If the project is not in a position to ensure the implementation of the project upon the occurrence of a risk event, you must implement the insurance risks. Insurance is, essentially, the transfer of certain risks of the insurance company.

As with increasing growth risks rising insurance rates, the amount the insurance company to insure the event at a small percentage of payment risks. Foreign practices of insurance uses full insurance of investment projects. Conditions of Russian reality can so far only partially to insure project risks: buildings, equipment, staff, some extreme situations, etc.

Select a sound insurance plan is a fairly complex task.

Classification by type of insurance, which provides insurance against financial risks, representing a combination of types of insurance with the insurer's coverage responsibilities of full or partial compensation for loss of income (expenses), on which the insurance contract (insured person) caused by the following events:

- stop production or reduction of production volumes as a result of specified events;
- job loss (for physical persons);
- bankruptcy;
- incidental expenses;
- failure (improper performance) the contractual obligations of the insured party, which is a lender on the transaction;
- the insured person incurred legal costs (costs);
- other events.

Insurance of financial risks in the case of the occurrence of each of the events specified in the classification shall be carried out by the insurer based on the specific insurance rules that take into account the specifics of the procedure and conditions for the insurance of insured risk and containing...
the exclusive list of insurance risks and insurance cases (that is, the amount of the liability of the insurer).

Insurers can implement this type of insurance only when this type of insurance is specified in the application for a license to carry on insurance business, which requires submission in the established order the documents that define the procedure and conditions of such insurance and country-based insurance obligations.

A type of property insurance is insurance business risk can be insured only insured the entrepreneurial risk and only in his favor. Business insurance risk in favor of a person other than the insured, shall be deemed concluded in favor of the insured.

At the conclusion of the insurance contract, the insurer the right to entrepreneurial risk to risk analysis and, if necessary, appoint an examination. Insurance risk assessment by the insurer is not required for the insured, which right to prove otherwise.

When insuring entrepreneurial risk, if not otherwise stipulated in the insurance contract, the insured amount may not exceed the actual cost (insured value). The cost for the business risks are losses from business activities, which the policyholder may be expected to be incurred upon occurrence of an insured event.

Allowed to create insurance funds or hedge funds to all enterprises and organizations for the financing of expenditure resulting from business and other risks, as well as insurance-related assets, the lives of workers and civil liability for damage caused to property interests of third parties. Installed and limit contributions to these objectives: it must not exceed one per cent of the volume of goods (works, services).

2.6 Planning of the reserves
Reservation of funds for unforeseen expenses is a way to deal with the risk of establishing correlations between potential risks that affect the cost of the project, and the size of the spending needed to address failures in the implementation of the project.

The reserve must equal or exceed the amount of vibration parameters of the system over time. In this case, the cost of the reserves should always be below costs (losses) related to the restoration. Foreign experience allows an increase in the project cost from 7 to 12 per cent by reserving funds on force majeure. Reservation of funds provides a relationship between the potential risk that modify the project cost, and the cost of breaking the violations in the course of its implementation.

Minimization of risks always increases project costs, but increases and project profitability.

The backup tools have the following sequence:

1) assessment of the potential impact of risks - i.e., amounts for unforeseen expenses. to this end, using all methods of risk analysis;
2) is determined by the structure of the reserve for unforeseen expenses. This structure can be entered into contracts or categories of costs (labour, materials, etc.);
3) determine the direction of the statutory reserve. such directions may be:
   1) funding for the newly revealed work on the project;
   2) increased funding to employment, for which insufficient funds were allocated;
   3) a version of the budget, taking into account, for which the necessary funds have not yet made;
   4) compensation for unforeseen changes to labor, overhead, etc., arise in the course of the project.

After performing the work for which the selected reserve for unforeseen expenses, you must compare the planned and actual allocation of unexpected expenses. The unused portion of the selected reserve returns to the reserve project.

Part of the reserve must always be available to the project manager (the rest of the reserve command, under the contract, other project participants).

Essential to the success of the project is exceeding the expected income from the project over cash outflows at each step of the calculation. In order to reduce the risks in terms of funding, you must create an adequate margin of safety, taking into account the following risks:
- the risk of unfinished construction (additional cost and lack of planned for this period income);
- the risk for the temporary reduction of sales of products of the project;
- tax risk (loss of use of tax credits and benefits, changes in tax laws);
- the risk of late payment of debts from customers.

In calculating the risks, you want real money accumulated surplus in the financial plan of the project at each step of the calculation was not less than 8% of planned spending on this step. In addition, it is necessary to provide additional sources of financing for the project and the creation of reserves, with payback in them a certain percentage of the proceeds from sales of the products.

2.7 Calculation of risk-weighted assets

One of the approaches is contingency planning the establishment of the so-called venture Fund. In fact, it is some way of self-insurance. This practice is common in captive insurance companies and enterprises. They form the insurance funds, one in the amount of 1% of the value of assets, the other is 1-5% of sales, some 3-5% of the Fund's annual payout to shareholders. The choice of the optimal size of the Fund is an important task in any business.

The optimal size of this Fund is one of the problems of risk management. This size is proportional to the degree of risk of the project.

The structure of venture fund should be defined according to the risk profile of the project. For this purpose the RBS (risk breakdown structure) can be applied. You must use the results of a risk analysis, in which we take into account both the severity of risk events and the probability of its occurrence.

Let establish venture fund RF in the amount of $k\%$ of the budget of the project ($B$).

$$ RF = \frac{k \cdot B}{100} $$

This Fund is designed to mitigate the consequences of $n$ risk events $R_1, R_2, \ldots, R_n$.

Experts estimate their risk dangers as $O_1, O_2, \ldots, O_n$.

Then the proportion of venture fund, designed to eliminate the consequences of i-risk ($RF_i$) can be defined as:

$$ RF_i = \frac{O_i}{\sum_{i=1}^{n} O_i} \cdot RF $$

The same approach, but applied in reverse order, can be applied to determine the total venture fund RF. Experts, identifying risk dangers as $O_1, O_2, \ldots, O_n$ shall appoint coefficients $k_i$, which would be the weights of risks and characterize the standard norm for unforeseen expenses to eliminate such risks. Value

$$ RF = \sum_{i=1}^{n} k_i O_i = \sum_{i=1}^{n} k_i p_i u_i $$

(where $p_i$ - probability of risk event, $u_i$- severity of this event) describes the average value of the venture fund.

To clarify the magnitude of the Fund we should take into account the probability of scattering characteristics $u_i$ and estimate variance

$$ D(RF) = \sum_{i=1}^{n} k_i^2 p_i^2 (1 - p_i) O_i = \sum_{i=1}^{n} k_i^2 (1 - p_i) O_i $$

Finally, we define the RF as
where \( t \) is the factor depending on chosen level of reliability.

(for level of hazard = 0.95, \( t=2.0 \))

### 2.8 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 [1] are based on the estimates that may not be optimal, but they are resistant to the possible variations from the assumed distribution models. These estimates are called robust estimates. The procedures of robust estimation are rather laborious. However, there are some software applications, such as SSP [10] and others, that can perform robust estimation algorithms.

Some robust procedures are available in MS Excel, for example, the function of truncated or trimmed mean \( \alpha \). To use this function the observations of a random variable should be put in ascending order:

\[
x(1) \leq x(2) \leq \ldots \leq x(n).
\]

Then for defined value \( \alpha \) (0<\( \alpha \)<1) should be calculated the parameter \( m = \left[ \frac{an}{2} \right] \) (integer of \( \frac{an}{2} \)). The truncated mean will be calculated as:

\[
\text{Tr}(\alpha) = \frac{1}{n-2m} \sum_{i=m+1}^{n} x(i).
\]

### 3. Results and Discussions

The methodology of risk management presented in this work formed the basis for recommendations on risk management in projects when training specialists in project management in Russia [1,13]. It was developed in accordance with the Project Management Body of Knowledge [12] and was recommended by the Russian Project Management Association SOVNET for Training Centers accredited by SOVNET in preparation for the 4-L-C IPMA certification.

The above methods were applied in managing the risks of a number of large construction innovation projects. The obtained experience of their application allows to conclude that along with the use of traditional methods, the use of robust procedures has proved to be productive. They made it possible to obtain sufficiently reliable results in situations of great uncertainty when making managerial decisions. As an example, we can present the Risk Management System developed on the basis of the methods proposed in the article and well-proven in the implementation of the Primorsky Territory Development Program and the construction of a bridge across the strait between Vladivostok and Russky Island. This system is software implemented in the framework of the SPIDER software package [11].

Traditional methods of analysis and risk management in projects were considered by leading scientists and are described in [12], as well as in the National Competence Requirements of Project Management Specialists [13]. Robust methods were developed for processing inhomogeneous populations [4,5]. In this paper, the main aspect is that the proposed methodology allows us to combine traditional methods that allow us to obtain optimal estimates with robust methods that give stable estimates.
4. Conclusion
The developed methodology of risk analysis and management in the project is a synergistic symbiosis of traditional and robust methods and is a theoretically grounded and practically tested tool that can be used in project management.

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