



Investment Risks by the Reconstruction of the Olympic Sports and Entertainment Complex

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Abstract: The paper examines the reliability of investment risk estimates based on probabilistic realizations of purpose-designed scenarios. The calculations of the probabilities of scenario realization were based on logical and probabilistic methods. The reliability of risk assessment is understood as the probability of successful completion of a project, fulfillment of all contractual obligations: construction in compliance with the architectural and engineering design and quality requirements, within the contractual period and approved budget. Investment risks were estimated based on seven primary scenarios. The realization of the risks of the main group depended on the realization of the various numbers of risk scenarios of each subgroup in the main group. For instance, the first scenario of the main group consisted in the risk of the impact of design errors, including errors in design and estimate documentation, incomplete working documentation. The second one consisted in the risk of the impact of construction errors that determine the quality of construction and installation work, the possibility of industrial accidents, etc. The risks of each subgroup could be obtained by means of expert estimations or, in case of sufficient statistical data, based on the actual distributions. A mathematical model was developed for the purpose of a computerized solution. The mathematical model also allowed identifying such dependability factors as “weight”, “significance” and “contribution” of each risk in the success of an investment project (reliability structure of investment risk estimation). The analysis of calculation data enabled the identification of the probability of successful project completion (reliability), the risks that are the most important, significant and having the largest contribution to the successful implementation of investment projects. Also, the risks were identified that have the least pronounced effect on the successful implementation of an investment project.

Keywords: Reliability, Probability, Investment, Model, Dependability, Risks, System, Scenarios

1. Introduction

The purpose of this article is to show the universality of logical-probabilistic methods using the example of assessing investment risks.

Previously, these methods were used only in assessing and regulating the reliability of technical (building) systems [1, 2, 4–8, 12, 15]. The use of these methods for solving economic problems is unknown to me.

The main advantage of the proposed method is its simplicity and availability. This method allows you to determine the contribution of each random factor in the overall assessment of investment risk. The mathematical model built to solve the investment risk problem also reveals the possibility of regulating the reliability of this estimate.

The mathematical model of investment risk assessment was built in Excel using elements of Boolean algebra. The initial data or initial probabilities in the example under consideration were taken on the basis of expert assessments. Note that with sufficient and stable statistics, the initial data can be obtained as a result of statistical modeling [1, 9].

2. The Content of the Article

By investment risk, we will understand the probability of an unsuccessful implementation of an investment project [3]. The opposite of an unsuccessful event will be the successful implementation of an investment project with the fulfillment of all contractual obligations: construction with

the required architectural and construction project quality, within the terms set by the contract and within the approved budget.

The algorithm for creating a mathematical model for risk assessment is as follows.

Select or designate major groups of factors.

Develop scenarios for main group factors. In this case, the number of scenarios is not limited, and the combination of random factors can be any.

For each factor of the main group, it is necessary to assign the so-called secondary groups of factors.

Develop scenarios for minor group factors. In this case, the number of scenarios is not limited, and the combination of random factors can be any.

Assemble a mathematical model (organize the logical connections of all scenarios).

Fill the model with the initial data for calculations.

Analyze the calculation results obtained, draw the appropriate conclusions and prepare a report.

For the considered example, the following main groups of factors were selected.

Q_1 – the impact of design errors, including errors in design and estimate documentation (DED), incomplete working documentation (WD);

Q_2 – the impact of construction errors that determine the quality of construction and installation work (CIW), the possibility of industrial accidents, etc.;

Q_3 – the impact of investment management errors that determine the timing of the project, the possibility of contract breakdowns, etc.;

Q_4 – the impact of unfavorable economic fluctuations, including economic sanctions, sharp fluctuations in the exchange rate, changes in other market indicators;

Q_5 – the influence of the unstable political situation in the country, the deterioration of the social background (strikes, ecology, etc.);

Q_6 – impact of cataclysms (earthquakes, floods, etc.);

Q_7 – influence of financial risks.

In turn, the realization of the risks of each group depends on the implementation of the scenarios of the factors included in the indicated groups. So, the first group of risks, taking into account the influence of design errors, including design and estimate documentation errors, incomplete design documentation, are:

Q_{1-1} – the risk of inaccurate calculation of the project payback;

Q_{2-1} – the risk of underestimating the construction budget;

Q_{3-1} – risk when choosing the main technological scheme and basic technological parameters;

Q_{4-1} – the risk caused by errors in the development of sections of architectural and structural solutions;

Q_{5-1} – risk caused by errors in the development of custom specifications and estimates;

Q_{6-1} – risk caused by delays in the development of working documentation;

Q_{7-1} – the risk of making biased design decisions;

Q_{8-1} – the risk of using materials that have no analogues;

Q_{9-1} – the risk of underestimating the construction time.

For the example under consideration, 7 scenarios were assigned from 9 factors of the first group, presented in Table 1.

Table 1. Design error impact scenarios.

Risks Q_{m-j} / Scenarios K_{ij}	Q_{1-1}	Q_{2-1}	Q_{3-1}	Q_{4-1}	Q_{5-1}	Q_{6-1}	Q_{7-1}	Q_{8-1}	Q_{9-1}
K_{1-1}	1	1	0	0	0	0	0	0	0
K_{2-1}	0	1	1	0	0	0	0	0	0
K_{3-1}	0	0	0	1	1	0	0	0	0
K_{4-1}	0	0	0	0	1	1	0	0	0
K_{5-1}	0	0	0	1	0	0	1	0	0
K_{6-1}	0	0	0	1	0	0	0	1	0
K_{7-1}	0	0	0	1	0	0	0	0	1

So, the first scenario consists of the risk of inaccurate calculation of the project payback *and* the risk of underestimating the construction budget. The second is the risk of underestimating the construction budget *and* the risk when choosing the main technological scheme and basic technological parameters, etc.

Thus, the likelihood of the influence of design errors, including design and estimate documentation errors, incomplete working documentation, Q_1 , is scripted implementation *either* K_{1-1} , *or* K_{2-1} , *or* K_{3-1} , *or* K_{4-1} , *or* K_{5-1} , *or* K_{6-1} , *or* K_{7-1} .

The second group of risks, taking into account the influence of construction errors that determine the quality of construction and installation works, the possibility of industrial accidents, etc., are:

Q_{1-2} – the risk of non-fulfillment of obligations by contractors and equipment suppliers;

Q_{2-2} – the risk of non-compliance with technological regulations in the production of construction and installation works;

Q_{3-2} – the risk of using materials that do not comply with design solutions;

Q_{4-2} – the risk of an increase in the construction time due to the fault of the general contractor;

Q_{5-2} – the risk of not reaching the technical indicators of the project;

Q_{6-2} – the risk of untimely commissioning of the facility;

Q_{7-2} – the risk of not receiving a package of permits.

Table 2 presents 6 scenarios out of 7 factors of the second group.

Table 2. Scenarios of the impact of construction errors.

Risks Q_{m-j} / Scenarios K_{i-j}	Q_{1-2}	Q_{2-2}	Q_{3-2}	Q_{4-2}	Q_{5-2}	Q_{6-2}	Q_{7-2}
K_{1-2}	1	1	0	0	0	0	0
K_{2-2}	0	1	1	0	0	0	0
K_{3-2}	0	1	0	1	0	0	0
K_{4-2}	1	0	0	0	1	0	0
K_{5-2}	0	0	0	0	1	1	0
K_{6-2}	1	1	1	0	0	0	1

The third group of risks, taking into account the impact of investment management errors that determine the timing of project implementation, the possibility of contract failures, etc., are:

Q_{1-3} – the risk of an error in the correctness of the chosen strategy;

Q_{2-3} – the risk of forecast error;

Q_{3-3} – the risk of organizational errors;

Q_{4-3} – risks of control and regulation errors.

Table 3 presents 3 scenarios out of 4 factors of the third group.

Table 3. Scenarios of the impact of investment management errors.

Risks Q_{m-j} / Scenarios K_{i-j}	Q_{1-3}	Q_{2-3}	Q_{3-3}	Q_{4-3}
K_{1-3}	1	1	0	0
K_{2-3}	1	0	1	0
K_{3-3}	0	0	1	1

The fourth group of risks, taking into account the impact of unfavorable economic fluctuations, including economic sanctions, sharp fluctuations in the exchange rate, changes in other market indicators, are:

Q_{1-4} – risk of impact of international economic sanctions;

Q_{2-4} – risk caused by sharp fluctuations in the exchange rate;

Q_{3-4} – the risk of incorrect assessment of market conditions: increased competition, etc.;

Q_{4-4} – the risk of incorrect assessment of market capacity;

Q_{5-4} – risk of misjudgment of market share.

Table 4 presents 5 scenarios out of 5 factors of the fourth group.

Table 4. Scenarios of the impact of adverse economic fluctuations.

Risks Q_{m-j} / Scenarios K_{i-j}	Q_{1-4}	Q_{2-4}	Q_{3-4}	Q_{4-4}	Q_{5-4}
K_{1-4}	1	0	0	0	0
K_{2-4}	0	1	0	0	0
K_{3-4}	0	0	1	0	0
K_{4-4}	0	0	0	1	0
K_{5-4}	0	0	0	0	1

The fifth group of risks takes into account the impact of the unstable political situation in the construction region and in the counterparty countries, including the deterioration of the social background (strikes, ecology, etc.):

Q_{1-5} – the risk of deteriorating social background;

Q_{2-5} – the risk of strikes with political slogans;

Q_{3-5} – the risk of environmental protests;

Q_{4-5} – the risk of demonstrations with political slogans.

Table 5 presents 3 scenarios out of 4 factors of the fifth group.

Table 5. Scenarios of the influence of the unstable political situation in the country.

Risks Q_{m-j} / Scenarios K_{i-j}	Q_{1-5}	Q_{2-5}	Q_{3-5}	Q_{4-5}
K_{1-5}	1	1	0	0
K_{2-5}	1	0	1	0
K_{3-5}	1	0	0	1

The sixth group of risks, taking into account the impact of disasters (earthquakes, floods, etc.), are:

Q_{1-6} – the risk of exceeding the calculated snow load;

Q_{2-6} – the risk of insufficient design measures for beyond design-basis loads;

Q_{3-6} – flood risk;

Q_{4-6} – the risk of landslides.

Table 6 presents 3 scenarios out of 4 factors of the sixth group.

Table 6. Scenarios of the influence of cataclysms.

Risks Q_{m-j} / Scenarios K_{i-j}	Q_{1-6}	Q_{2-6}	Q_{3-6}	Q_{4-6}
K_{1-6}	1	1	0	0
K_{2-6}	1	0	1	0
K_{3-6}	1	0	0	1

The seventh group of risks that take into account the impact of financial disturbances are:

Q_{1-7} – the risk of inability to obtain a bank loan;

Q_{2-7} – the risk of changes in the rate on a bank loan;

Q_{3-7} – the risk of lack of own working capital for the investor's company;

Q_{4-7} – the risk of financial losses as a result of changes in the exchange rate that may occur in the period between the conclusion of the contract and the actual settlement of it;

Q_{5-7} – the risk of depreciation of the real cost of capital (inflationary, in the form of financial assets of an enterprise), as well as the risk of expected income from financial transactions in an inflationary environment;

Q_{6-7} – tax risk: the likelihood of introducing new types of taxes and fees for the implementation of certain aspects of economic activity; the possibility of increasing the level of rates of existing taxes and fees; changes in the terms and conditions for the implementation of certain taxes; the likelihood of the cancellation of existing tax benefits in the field of economic activities of the enterprise;

Q_{7-7} – structural risk: ineffective financing of the current costs of the enterprise, causing a high proportion of fixed costs in their total amount.

Table 7 presents 6 scenarios out of 7 factors of the seventh group.

Table 7. Financial risk impact scenarios.

Risks Q_{m-j} / Scenarios K_{i-j}	Q_{1-7}	Q_{2-7}	Q_{3-7}	Q_{4-7}	Q_{5-7}	Q_{6-7}	Q_{7-7}
K_{1-7}	1	1	0	0	0	0	0
K_{2-7}	0	1	1	0	0	0	0
K_{3-7}	0	0	1	1	0	0	0
K_{4-7}	0	0	0	1	1	0	0
K_{5-7}	0	0	0	0	1	1	0
K_{6-7}	0	0	0	0	0	1	1

In tables 1-7: Q_i – probability of occurrence of the i -th risk; K_i – scenarios from logical conjunctions.

Losses of the company (investment "failure") are associated with the implementation of the risk scenarios presented in Table 8: either (Q_1 and Q_3), or (Q_1 and Q_6), or

(Q_2 and Q_3), or (Q_2 and Q_5 and Q_6), or (Q_1 and Q_3 and Q_4), or (Q_1 and Q_3 and Q_5), or (Q_3 and Q_4 and Q_5 and Q_6), or (Q_7).

Table 8 presents 8 scenarios out of 7 factors of "failed" investment.

Table 8. Scenarios of unsuccessful investment.

Risks Q_{m-j} / Scenarios K_{i-j}	Q_1	Q_2	Q_3	Q_4	Q_5	Q_6	Q_7
K_1	1	0	1	0	0	0	0
K_2	1	0	0	0	0	1	0
K_3	0	1	1	0	0	0	0
K_4	0	1	0	0	1	1	0
K_5	1	0	1	1	0	0	0
K_6	1	0	1	0	1	0	0
K_7	0	0	1	1	1	1	0
K_8	0	0	0	0	0	0	1

In tables 1-8: 1 (unit) means accounting for an event (random factor); 0 (zero) - ignoring a random factor.

The initial data for Q_i , $i = 1, \dots, 7$ are the probabilities determined using the scenarios of tables 1-7.

In table 9, for the example under consideration, the initial data for performing the calculations are given. Risks Q_{i-j}

(the probability of realization of i risks of the j -th group) in the example under consideration are taken by means of expert assessments; the event R_i is the opposite of the risk Q_i . If the statistical data are sufficient, the probabilities Q_{i-j} are recommended to be determined by the actual distributions, for example, using the Pearson distribution curves.

Table 9. Initial data.

R_{1-1}	R_{2-1}	R_{3-1}	R_{4-1}	R_{5-1}	R_{6-1}	R_{7-1}	R_{8-1}	R_{9-1}
0.850	0.850	0.850	0.800	0.750	0.250	0.900	0.900	0.600
Q_{1-1}	Q_{2-1}	Q_{3-1}	Q_{4-1}	Q_{5-1}	Q_{6-1}	Q_{7-1}	Q_{8-1}	Q_{9-1}
0.150	0.150	0.150	0.200	0.250	0.750	0.100	0.100	0.400
R_{1-2}	R_{2-2}	R_{3-2}	R_{4-2}	R_{5-2}	R_{6-2}	R_{7-2}	–	–
0.900	0.300	0.900	0.500	0.600	0.700	0.990	–	–
Q_{1-2}	Q_{2-2}	Q_{3-2}	Q_{4-2}	Q_{5-2}	Q_{6-2}	Q_{7-2}	–	–
0.100	0.700	0.100	0.500	0.400	0.300	0.010	–	–
R_{1-3}	R_{2-3}	R_{3-3}	R_{4-3}	–	–	–	–	–
0.500	0.750	0.750	0.600	–	–	–	–	–
Q_{1-3}	Q_{2-3}	Q_{3-3}	Q_{4-3}	–	–	–	–	–
0.500	0.250	0.250	0.400	–	–	–	–	–
R_{1-4}	R_{2-4}	R_{3-4}	R_{4-4}	R_{5-4}	–	–	–	–
0.750	0.750	0.900	0.850	0.850	–	–	–	–
Q_{1-4}	Q_{2-4}	Q_{3-4}	Q_{4-4}	Q_{5-4}	–	–	–	–
0.250	0.250	0.100	0.150	0.150	–	–	–	–
R_{1-5}	R_{2-5}	R_{3-5}	R_{4-5}	–	–	–	–	–
0.600	0.750	0.950	0.750	–	–	–	–	–
Q_{1-5}	Q_{2-5}	Q_{3-5}	Q_{4-5}	–	–	–	–	–
0.400	0.250	0.050	0.250	–	–	–	–	–
R_{1-6}	R_{2-6}	R_{3-6}	R_{4-6}	–	–	–	–	–
0.900	0.950	0.950	0.950	–	–	–	–	–
Q_{1-6}	Q_{2-6}	Q_{3-6}	Q_{4-6}	–	–	–	–	–
0.100	0.050	0.050	0.050	–	–	–	–	–
R_{1-2}	R_{2-2}	R_{3-2}	R_{4-2}	R_{5-2}	R_{6-2}	R_{7-2}	–	–
0.999	0.950	0.999	0.750	0.850	0.950	0.750	–	–
Q_{1-2}	Q_{2-2}	Q_{3-2}	Q_{4-2}	Q_{5-2}	Q_{6-2}	Q_{7-2}	–	–
0.001	0.050	0.001	0.250	0.150	0.050	0.250	–	–

In table 9 Q_i - probability of realization of the i -th risk; R_i - on the contrary, the probability of unrealisation of the i -th risk, that is, $R_{i-j} = 1 - Q_{i-j}$.

Let's write down the probability of losses for LC for the above example in mathematical disjunctive normal form:

$$LC = 1 - \left(\begin{array}{c|c} K_1 & Q_1 Q_3 \\ K_2 & Q_1 Q_6 \\ K_3 & Q_2 Q_3 \\ K_4 & Q_2 Q_5 Q_6 \\ K_5 & Q_1 Q_3 Q_4 \\ K_6 & Q_1 Q_3 Q_5 \\ K_7 & Q_3 Q_4 Q_5 Q_6 \\ K_8 & Q_7 \end{array} \right) = 1 - \left(\begin{array}{c} Q_1 Q_3 \\ Q_1 Q_6 \\ Q_2 Q_3 \\ Q_2 Q_5 Q_6 \\ Q_1 Q_3 Q_4 \\ Q_1 Q_3 Q_5 \\ Q_3 Q_4 Q_5 Q_6 \\ Q_7 \end{array} \right). \quad (1)$$

From (1) it follows that each scenario is a multi-criteria value. To solve the problem of taking into account all risks, it is necessary to describe the implementation of possible "unsuccessful" scenarios, that is, it is necessary to understand under what conditions a "failure" (refusal) can occur. Table 8 shows the failure scenarios according to (1).

Thus, the mathematical model is assembled. The probability of successful implementation of the project, taking into account the probabilities indicated in Table 9, was 0.77688. Therefore, the probability of "failure" or loss is 22.3%. The mathematical model allows one to determine such parameters as "weight" (2), as well as "significance" (3) and "contribution" (4) of each risk to the success of an investment project. The calculation results for parameters (2) - (4) are presented in Table 10.

$$g_{Q_i} = \frac{G\{\Delta_{Q_i} y(Q_1, \dots, Q_n)\}}{2^n} = \sum_{j=1}^l 2^{-(r_j-1)} - \sum_{f=1}^k 2^{-(r_f-1)}, \quad (2)$$

where $f = 1, \dots, k; j = 1, \dots, l; r_f, r_j$ - ranks of elementary conjunctions; k, l - the number of conjunctions containing Q'_i, Q_i ($Q'_i = R_i$) and not containing the i -th argument; n is the number of independent variables of the original function.

The "weight" of the Boolean difference (2) characterizes the importance of the risk Q_i for the reliability of investments. The "weight" of an element also characterizes the relative number of such critical states in which the failure

of a given element leads to a failure of the entire model (and, conversely, its restoration leads to restoration), among all states of the system with $Q_i = 1$. Criterion "weight" g_{x_i} of an element characterizes the location of the given element Q_i in the system $y(Q_1, \dots, Q_n)$.

The "significance" of the element Q_i in the system $y(Q_1, \dots, Q_n)$ is the partial derivative of the probability of failure-free operation of the system R_c in terms of the probability of failure-free operation of the element R_i , that is

$$\zeta_{Q_i} = \frac{\partial P\{y(Q_1, \dots, Q_n) = 1\}}{\partial P\{Q_i = 1\}} = \frac{\partial R_c}{\partial R_i}. \quad (3)$$

The criterion "significance" characterizes the rate of change in the reliability of investments. "Significance" is the conditional probability of the risk Q_i being realized. In addition, the criterion "significance" allows you to determine the risks that provide the maximum increase in the reliability of the selected model.

The "contribution" of the Q_i element in the system (risk scenarios) $y(Q_1, \dots, Q_n)$ is the product of the probability of failure-free operation of the R_i element by its "significance", that is

$$B_{x_i} = R_i \frac{\partial R_c}{\partial R_i} = R_i \frac{R_c - R_{c0}^{(i)}}{R_i} = R_c - R_{c0}^{(i)}. \quad (4)$$

The criterion "contribution" characterizes the increase in reliability after the restoration of the element Q_i with the actual probability of its failure-free operation equal to R_i .

The concept of "specific contribution" is a more universal characteristic than just "contribution". The "specific contribution" of the element Q_i in the system $y(Q_1, \dots, Q_n)$ is the normalized "contribution" of this element, that is

$$b_{Q_i} = B_{Q_i} / \sum_{i=1}^n B_{Q_i}. \quad (5)$$

The calculation results in the form of differential characteristics of the elements $g_{Q_i}, \zeta_{Q_i}, b_{Q_i}$ presented in Table 10 allow you to clearly see the distribution of the roles of all factors of the mathematical model when solving the problem under consideration.

Table 10. Calculation results in the form of differential characteristics of elements.

g_1	g_2	g_3	g_4	g_5	g_6	g_7
0.203	0.141	0.234	0.016	0.047	0.172	0.453
ζ_1	ζ_2	ζ_3	ζ_4	ζ_5	ζ_6	ζ_7
0.13714	0.17711	0.61049	0.00024	0.00419	0.26718	0.82126
B_1	B_2	B_3	B_4	B_5	B_6	B_7
0.04213	0.08765	0.16407	0.00015	0.00078	0.00381	0.04438
b_1	b_2	b_3	b_4	b_5	b_6	b_7
0.123	0.256	0.478	0.000	0.002	0.011	0.129

Table 11 shows the relative values of the risk parameters $p_i (i = 1, \dots, 7)$, which were obtained according to (6):

$$p_i = p_i / p_{max}. \quad (6)$$

Table 11. Relative values of risk parameters.

g_1	g_2	g_3	g_4	g_5	g_6	g_7
0.45	0.31	0.52	0.03	0.10	0.38	1.00
ξ_1	ξ_2	ξ_3	ξ_4	ξ_5	ξ_6	ξ_7
0.17	0.22	0.74	0.00	0.01	0.33	1.00
b_1	b_2	b_3	b_4	b_5	b_6	b_7
0.26	0.53	1.00	0.00	0.02	0.09	1.00

3. Conclusions

The proposed mathematical model is universal. It can be used, for example, to assess the reliability of statically indeterminate bar building structures [1] and other complex technical systems [13, 14]. To do this, it is enough to create scenarios in accordance with the schemes of destruction of the considered technical system [10 – 11].

The model is simple to assemble and easy to operate.

The model makes it easy to determine the importance and significance of each factor for a particular calculation and to draw the corresponding correct conclusions.

Analysis of the calculation results in the considered example allows us to draw the following conclusions.

The probability of successful implementation of the project under the scenarios indicated in Table 8 was 77.68%. Therefore, the risk (probability of "failure") is 22.32%.

The most important and significant, as well as those having the greatest contribution to the investment project, are the risks of the impact of investment management errors Q_3 and financial Q_7 .

The probability of successful implementation of the investment project under consideration is least influenced by Q_4 – the influence of unfavorable economic fluctuations and Q_5 – the influence of the unstable political situation in the country.

The distribution of the importance, significance and contribution of all investment factors influencing the successful implementation of the project in the considered example is presented in Table 11.

4. Data Availability Statement

Some or all data, models, or code that support the findings of this study are available from the corresponding author upon reasonable request.

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