Determination of the parameters of the general contractor selection model for the successful implementation of the construction project

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Abstract. The authors examined the organization of interaction between the technical customer and the general contracting organization and revealed that it is at the stage of construction of facilities that difficulties arise in the interaction of construction participants, which were not initially taken into account when signing the construction contract. The implementation of the construction project depends on the effective organization of construction. The construction is characterized by dynamism and a high level of coordination of construction participants, which indicates the appearance of additional costs for both the technical customer and the contractor. To reduce the level of possible risks, the authors proposed at the initial stage of construction to exclude or reduce the impact of risk factors associated with the choice of an inefficient sub-row organization. 6 most important and relevant risk factors in the field of interaction between the technical customer and the contractor have been identified and analyzed. Expert surveys were conducted to determine the weight coefficients of damage and the probability of occurrence of risk factors. The reliability of the results was confirmed by calculating the multiple correlation coefficient.

1. Introduction

Currently, the issue of optimizing the selection of a reliable general contracting organization based on the most important criteria that affect the execution of a construction project remains relevant. It should be noted that the client, when implementing an investment-construction project, entrusts the responsibility for coordinating the participants in the construction process and timely responding to changes in the project to the project executor. The quality of the work performed and the project's profitability depend on the approach to organizing the construction process and the methodology for evaluating the general contractor [1]. The contract bidding system in construction is part of an integrated dynamically developing construction project management system. The existing tender system in Russia is imperfect. It implies the placement of tenders on electronic portals, where participants submit applications for participation. Such a mechanism for selecting a contracting organization is legally valid but poses a risk to the construction project - intentional underestimation of the contract cost among participants [2]. When bidding, the customer primarily pursues the goal of minimizing expenses when creating a project and

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optimizing the timing of construction work, therefore, more often the choice is made in favour of the contracting organization that offered the most favourable conditions for the cost of the work [3]. A certain number of requirements are presented to a potential contractor, the main of which is a positive reputation and the absence of financial debts [4]. In international practice, the issue of tenders is relevant, the study of the possibility of conducting electronic bidding from the point of view of legality is of great interest [5]. The tender system is also being considered in terms of minimizing corruption risks, and there is a need to improve the process of collecting data on tenders for government contracts [6]. The authors of the study, after analyzing the process of organizing tenders, have identified the following problem: the main criterion for determining the winner of the tender is the most advantageous, the lowest among all, commercial proposal for the execution of construction work, and there are no effective tools for a comprehensive assessment of a construction company based on multiple criteria.

The hypothesis is put forward – for the successful organization of the construction process, it is not enough to estimate only the cost of the services of a general contractor, it is more effective to assess the material and labor capabilities of the company, taking into account potential risks and determining the input parameters of the model. The purpose of the current study was to calculate the most important parameters necessary for the selection of a general contracting organization – the damage coefficients of risk factors and the probability of risk occurrence. In international practice, the issue of the need to verify reliability data obtained based on expert assessments is relevant [7-10].

2. Research methods

The authors, using the methods of system analysis and expert assessments, identified the most important risks that a technical customer and a contractor may face at the beginning of the construction of an object. The results of the expert survey are presented in Table 1.

Table 1. Risk identification

№	Name of the risk	Risk indicator	Index
1	Insolvency of the developer	Attracting unreliable investment companies	f_{11}
		Untimely attraction of funds for the implementation of the project on time	f_{12}
		Incorrect assessment of own budget/investments	f_{13}
		Violation in the budget planning system/lack of a budget development schedule	f_{14}
2	Non-compliance of the contractor's resources to complete the project on time	Mismatch of material resources (warehouses, cabins)	f_{21}
		Mismatch of construction machinery and equipment	f_{22}
		Mismatch of labor resources – workers and ITR	f_{23}
		Mismatch of tools and inventory	f_{24}
3	Making mistakes in project documentation	Low level of input control of initial permits	f_{31}
		Low quality of input control of project documentation by the technical customer	f_{32}
		Low quality of input control of project documentation by the contractor	f_{33}

		Low experience of a contractor with similar projects	f_{34}
4	Lack of provision of a given level of project quality	Application of new, little-studied technologies in construction	f_{41}
		Low quality of the work production project	f_{42}
		Poor quality of drafting executive documentation	f_{43}
		Non-conformity of workers' qualifications	f_{44}
5	Low level of organization of the construction control system of the customer/ contractor	Lack of experience working with this type of capital object page	f_{51}
		Lack of necessary logistical support	f_{52}
		Inconsistency of the allocated staff of employees carrying out construction control	f_{53}
		Discrepancy in the qualifications of employees performing construction control	f_{54}
6	Occurrence of emergency situations on the construction site	Injury statistics at previous facilities	f_{61}
		Insufficient number of occupational safety engineers	f_{62}
		Non-conformity of workers' qualifications	f_{63}
		Poor quality of provision of personal protective equipment at the construction site	f_{64}

Financing and attracting investments are of great importance in the management of construction projects. To reduce the likelihood of financial risk, the authors consider it necessary for general contracting organizations to regularly maintain a schedule for budget development both for a short period of time - the nearest month, and in the long term - for a year. It is also necessary to monitor payments to suppliers of construction equipment and materials and plan purchases in advance. The authors of the study propose to be guided by the budget development plan presented in Figure 1.

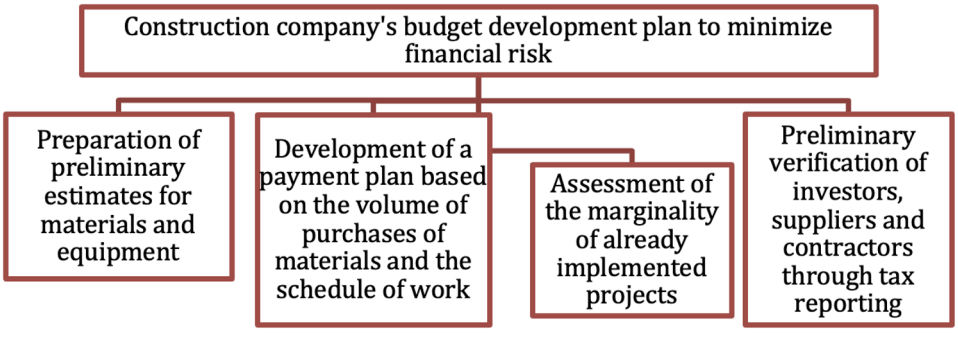


Fig. 1. Block diagram of the budget development of a construction company to minimize financial risk.

Another significant risk in construction is the contractor's lack of resources to complete the project on time. Timely identification of this discrepancy allows the client to make a decision on whether the contractor is capable of executing the construction project. The absence of ensuring the desired level of project quality poses a great risk to the implementation of the construction project. To ensure high-quality construction, the

contractor should develop a production project, prepare executive documentation, and assemble a team of qualified workers.

The next considerable risk of a construction project at the beginning of its implementation

is a low level of organization of the construction control system. Organizations that carry out construction control (contractor, technical contractor) must have an optimal number and qualification of employees, as well as all necessary permits. The most common risk during the construction of a capital construction project is the occurrence of accidents on the construction site. The safety risk taken into account in advance will help to save the lives of employees in the future and minimize financial risks due to all costs associated with the elimination of the consequences of the accident.

3. Results

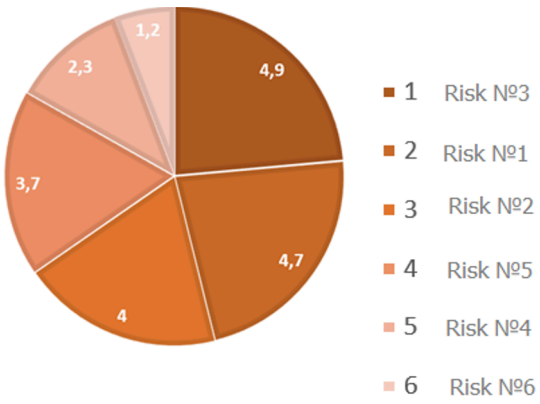
The study used the method of expert assessment [11] to determine the weight coefficients of the damage of the identified risks. The algorithm of the expert assessment can be divided into several stages [12]:

I. At the preparatory stage of the expert assessment, the composition of the working group

was determined. The expert group consisted of 6 specialists in the construction sector – heads of construction projects, civil engineers, chief project engineers and engineers of the production and technical department. The candidates were selected based on the following factors:

- the candidate's competence in this field;
- stability of work in the construction sector (work experience);

II. Expert assessment. The formed expert group ranked the risks according to the degree of damage in case of realization of each risk. The results are shown in Figure 2.



Risk №3 – Making mistakes in project documentation;
Risk №1 – Insolvency of the developer;
Risk №2 – Non-compliance of the contractor's resources to complete the project on time;
Risk №5 – Low level of organization of the construction control system of the customer/contractor;
Risk №4 – Lack of provision of a given level of project quality;
Risk №6 – Occurrence of emergency situations on the construction site

Fig. 2. Pie chart of the results of the expert survey before data processing to determine the damage weighting factor

III. Processing of results. The experts' opinions were collected through individual questionnaires. When processing the results to determine the relationship between an arbitrary number of ranked attributes, the multiple concordance coefficient was used, which

reflects the agreement of experts' opinions [13]. In the case of the ranking method, the Kendall concordance coefficient (W) is calculated using the following formula:

$$W = \frac{12S}{k^2 \cdot (n^3 - n)} \quad (1)$$

where W – concordance coefficient;
S – the sum of the squares of the ranks is calculated by the formula (2);
n – number of objects;
k – number of experts.

$$S = \sum_i \left(\sum_j R_{ij}\right)^2 - \frac{\left[\sum\sum R_{ij}\right]^2}{n} \quad (2)$$

where R_{ij} – rank the i-th object evaluated by the j-th expert;

We calculate by the formula (2) for the weight coefficient of damage:

$$S = \sum_i \left(\sum_j 21,1\right)^2 - \frac{[21,1]^2}{6} = 371 \quad (3)$$

Next, using the formula (1), we calculate the Kendell concordance coefficient (W) for the weight coefficient of damage:

$$W = \frac{12 \cdot 371}{6^2 \cdot (6^3 - 6)} = 0,58 \quad (4)$$

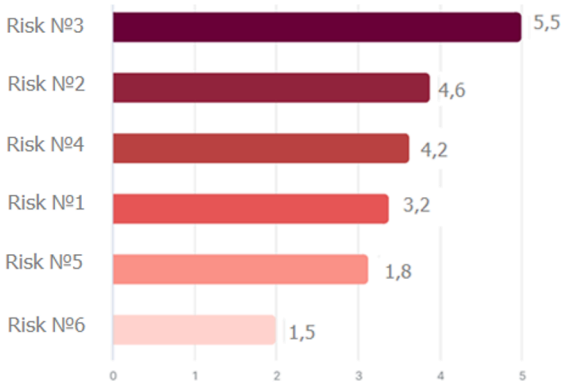
According to [14], the Kendell concordance coefficient can vary from 0 to 1. ($W \geq 0.5$), respectively, there is a certain agreement between experts. The result of processing the expert survey for the damage weighting factor in the software and computing complex is shown in Figure3. We will accept x_1 = Risk №1; x_2 = Risk №2; x_2 = Risk №2; x_3 = Risk №3;
x_4 = Risk №4; x_5 = Risk №5; x_6 = Risk №6.

Матрица рангов

Факторы / Эксперты	1	2	3	4	5	6	Сумма рангов	d	d²
x_1	5	5.5	3	5.5	5.5	4	28.5	7.5	56.25
x_2	4	4	4	3.5	5.5	3	24	3	9
x_3	6	3	5.5	5.5	4	5.5	29.5	8.5	72.25
x_4	3	2	2	2	3	2	14	-7	49
x_5	1.5	5.5	5.5	3.5	1	5.5	22.5	1.5	2.25
x_6	1.5	1	1	1	2	1	7.5	-13.5	182.25
∑	21	21	21	21	21	21	126		371

Fig 3. Matrix of expert survey ranks to assess the significance of damage risks

To determine the probability coefficient of the occurrence of risk factors, the second stage of the expert survey was conducted, the results of which are shown in Figure 3.



Risk №3 – Making mistakes in project documentation;
Risk №2 – Non-compliance of the contractor's resources to complete the project on time;
Risk №4 – Lack of provision of a given level of project quality;
Risk №1 – Insolvency of the developer;
Risk №5 – Low level of organization of the construction control system of the customer/contractor;
Risk №6 – Occurrence of emergency situations on the construction site

Fig. 4. Horizontal diagram of the results of the expert survey before data processing to determine the probability weighting factor

We calculate by the formula (2) for the weighting coefficient of the probability of occurrence:

$$S = \sum_i (\sum_j 23,4)^2 - \frac{[23,4]^2}{6} = 458 \quad (5)$$

Next, using the formula (1), we calculate the Kendell concordance coefficient (W) for the weight coefficient of damage:

$$W = \frac{12 \cdot 458}{6^2 \cdot (6^3 - 6)} = 0,73 \quad (6)$$

(W ≥ 0.5), respectively, there is a certain agreement between the experts. The result of processing an expert survey for the probability occurrence coefficient in a software and computing complex shown in Figure 5. We will accept x_1 = Risk №1; x_2 = Risk №2; x_2 = Risk №2; x_3 = Risk №3; x_4 = Risk №4; x_5 = Risk №5; x_6 = Risk №6.

Матрица рангов

Факторы / Эксперты	1	2	3	4	5	6	Сумма рангов	d	d^2
x_1	3	3	3	2.5	2.5	5.5	19.5	-1.5	2.25
x_2	5	5	5	5	5	3	28	7	49
x_3	6	6	6	6	6	3	33	12	144
x_4	4	4	4	4	4	5.5	25.5	4.5	20.25
x_5	2	2	2	1	1	3	11	-10	100
x_6	1	1	1	2.5	2.5	1	9	-12	144
∑	21	21	21	21	21	21	126		459.5

Fig. 5. Matrix of expert survey ranks to assess the probability of risk occurrence

According to [13], the hypothesis of non-randomness of expert agreement is confirmed if the following inequality holds:

$$\chi_p^2 > \chi_T^2 \quad (7)$$

$$\chi_p^2 = W \cdot k \cdot (n - 1) \quad (8)$$

where χ_p^2 – where is the calculated value of the Pearson criterion;

χ_T^2 - the tabular value of the Pearson criterion;

According to the formula (8) for the weight coefficient of damage:

$$\chi_p^2 = 0,58 \cdot 6 \cdot (6 - 1) = 17,4 \quad (9)$$

In accordance with [15] we accept: $\chi_T^2 = 0,2; \chi_p^2 < \chi_T^2$ => the condition is not met, it is necessary to interview more experts.

According to the formula (8) for the probability coefficient of occurrence of risk factors:

$$\chi_p^2 = 0,73 \cdot 6 \cdot (6 - 1) = 21,9 \quad (10)$$

In accordance with [15] we accept: $\chi_T^2 = 0,2; \chi_p^2 > \chi_T^2$ => the condition is met.

4. Discussion of the results

The main risks for the construction project in the relationship between the customer and the general contractor are identified. The degree of significance of the construction project risks and the probability of their occurrence were determined using methods of statistical data processing. The authors of the study formed the composition of the expert group and conducted two expert surveys using the ranking method. When conducting statistical studies, a statistical indicator was used to determine the reliability of the results obtained, which allows us to assess the degree of consistency and convergence between several variables. The research results were verified in a computational complex with the output of a rank matrix for each expert survey. By calculating the Kendall's concordance coefficient, the authors tested the hypothesis of non-random agreement among experts.

5. Conclusion

The article provides an overview of scientific research on the organization of construction bidding and methods of conducting expert surveys to determine the consistency of expert opinions during the survey. The relevance of applying a risk-oriented approach in selecting a reliable contractor for a construction project is justified. The purpose of the study is fulfilled: the most important parameters and their weighting coefficients for the evaluation model of the choice of a general contractor organization have been determined. The reliability of the coefficients obtained by the expert method has been confirmed. Further research will include calculating the overall risk of the construction project, conducting a field test on a specific construction project, and developing a risk assessment scale and a list of measures to mitigate risk factors.

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