Basic provisions for forming the parameter-oriented model of contractors selection under the conditions of engineering control scheme

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Abstract. The theoretical foundations and methodological principles of forming a parameter-oriented model for selecting contractors under the conditions of an engineering control scheme are considered in the article. Recommendations are given on the effective use of limited resources, increasing the competitiveness of construction organizations. Promising directions of further scientific research are enumerated. Overcoming negative phenomena in the Russian economy is closely connected with the successful solution of tasks in its investment and construction sphere, based on an effective management system.

1. Introduction

In accordance with the earlier adopted paradigm [1], the investment and development complex, as a variety of technical and economic systems that are a particular case of dynamic systems, is a functional subsystem of a society in which production, distribution and consumption of material goods are realized, and which is characterized by the great complexity of the relationships, permanent progressive development, clearly expressed hierarchy, as well as the presence of a large number of factors predominantly stochastic in nature. On a separate note, we should mention the instability of the technical and economic system, as its specific feature. In this regard, one of the most important tasks is to ensure the so-called homeostatic equilibrium – an equilibrium state or close to it due to regulatory impact.

By regulatory impacts is meant impacts, the values and intensity of which can be managed and corrected for the motion of systems in a given direction, advantageous in comparison with other possible directions. In other words, regulatory impacts are specific signals transmitted to the technical and economic system that carry information about the required actions to change it.

The analysis carried out in the framework of the research [1, 2, 3] showed that one of the important elements of the theory and practice of the organization and management of construction operations is the functions that allow to identify the essence and content of the management process itself, to build a hierarchy of the engineering management scheme in the investment and development complex, identify shortcomings of traditional structures, update them, and verify internal reserves to improve corporate efficiency.

A construction company can adapt to the external environment only through an organizational structure. To adequately respond to changes in the environment, the organizational structure must have a significant degree of flexibility, i.e., the speed of the management processes should be
increased many times over. Common (traditional) organizational structures no longer correspond to this requirement. The effectiveness of the interaction under the scheme “customer – engineering company” is much higher in comparison with the classical scheme “customer – general design engineer; general contractor; organizations that carry out commissioning and start-up of equipment; suppliers of materials and equipment”. In addition, the process of integrating the activities of design and contracting units was objectively launched with the aim of achieving a synergistic effect, as well as increasing the level of responsibility of project organization employees for the final result and strengthening the role of construction organizations’ experts in decision-making. Therefore, in the current economic situation, the engineering scheme for managing investment and construction projects is becoming more and more in demand and is a natural stage in the modern development of the construction industry.

2. Review of literature

At the same time, it should be noted that the state of the technical and economic system assumes permanent reasonable and relevant intervention of the managing subsystem that ensures a balanced and sustainable development of investment and construction activities, and observance of the necessary structural proportions. In certain periods, such interference can cause fluctuations about the point of momentary equilibrium when moving along the trajectory of growth, the amplitude of such fluctuations is determined by external and internal conditions of functioning.

In these cases, the amplitude of the fluctuations is extinguished due to the presence of feedback, which facilitates the adoption of reasonable management decisions that return investment and construction activities to the trajectory of sustainable growth in the shortest possible time and at minimal costs. At the level of “construction site – construction facility” such an effective regulator can be the developer and the projected organizational scheme of management based on engineering implemented by him.

Based on the above features of modern domestic investment and construction activities and trends in its development, an analysis was made of the regulatory and legal framework for the organization of procurement activities in the construction industry, and on its basis possible directions for improvement in relation to the subject of research are shown [4].

As part of the study [4–19], a procedure for selecting the counterparty’s proposals was formed; a classification of the parameters was made in the context of evaluating counterparties’ proposals when verifying the developer and contractors within the engineering management strategy.

3. Materials and methods

The procedure for selecting counterparties’ proposals involves two stages:

1) arranging proposals in accordance with organizational and technological reliability;
2) estimating comparative economic efficiency of options of the developer and contractors selection.

The main criteria of organizational and technological reliability, according to which it is possible to evaluate and then arrange proposals, both the developer and contractors within the engineering management scheme of investment and construction activities, are: the cost of work; duration of work performance; organization of works and compliance with technical requirements of the tender documentation; qualification of the applicant and its reliability; financial and economic situation of the applicant; payment scheme for work performed.

These criteria have their own decomposition. In this regard, the following classification of criteria and parameters is proposed:

1. Cost of works. This criterion assumes: cost proposals; cost structure; cost calculation on the basis of aggregated indicators (comparable objects); financing schedule; justification for a cost-cutting.
2. Duration of works. The criterion includes: the total duration of work; availability of approvals (for the developer of construction with contractors, and for contractors with subcontractors);
availability of agreements with suppliers of material and technical resources; the importance of float time in basic works; the degree of the work schedule specification.

3. Organization of work and compliance with technical requirements of the tender documentation. Such criterion identifies the parameters that characterize such components of the construction as: preparation of the construction site; arrangement of on-site networks and structures; arrangement of engineering equipment and facilities; preparation of works on engineering equipment for buildings and constructions; construction of major buildings and structures; accomplishment of site improvement works; arrangement of approach roads; implementation of measures for safety and environmental protection; implementation of measures to commission the facility; ensuring resource and energy saving, compliance with project documentation; provision of guarantees.

4. Qualification of the contractor and its reliability. The criterion includes indicators that determine: the availability of certificates, qualifications, licenses; functioning of an effective quality control system; number of competitions of a similar profile for the last 3 years, in which the contractor took part; the number of similar competitions won for the past 3 years; experience of cooperation with the customer; participation in arbitration and other proceedings; number of specialists with specialized certificates; a park of specialized machinery and specialized equipment; experience in doing similar work; duration of the organization activities; the number of similar facilities commissioned; customer reviews.

5. The financial and economic situation of the contractor. The criterion is made up of such indicators: the annual amount of work (of them by own strength); increase (decrease) in the portfolio of orders by the previous year (in percent); depreciable value of equity; the residual value of fixed assets; cost of rented funds; arrears on obligatory payments; arrears of wages; profit (or loss) for the reporting year.

6. Calculation scheme for the work performed: progress payment for the actual work performed; payment provide for an advance of 30% and attraction of bank guarantees (pledge), or stage-by-stage payment of works with the first advance payment of 30%; a payment that provides an advance of 50% and bank guarantees (pledge), or a progress payment of work performed with the first advance payment of 50%; a payment that provides an advance of 30%; payment that includes an advance payment of 50%.

4. Research results

The second stage of the procedure for selecting proposals of applicants involves a comparative evaluation of the economic efficiency of options for the organization of investment and construction projects, which reflect the following parameters: net present value – NPV; internal rate of return – IRR, profitability index – PI; discounted payback period.

Proposals of contractors in the tenders of the developer and contractors, one way or another, are related to the cost of work and the timing of their implementation, which directly affects the efficiency of the implementation of the investment and construction project. Also, in rare cases, when the project (taking into account the proposals of the applicants) is certainly acceptable in accordance with all the criteria of organizational and technological reliability, that’s why there is a need for a comparative evaluation of economic efficiency in the procedure for selecting contractor proposals.

The following solution of the task is possible. The main criterion is chosen, and the rest are used as constraints. As the main criterion, as a rule, NPV is used, but more and more often recently IRR is also used. In the procedure for evaluating and ranging proposals of applicants, the equilibrium use of all criteria is achieved by integrating them into one performance indicator, in this terms each receives a certain significance value.

In the authors’ studies [2, 3], an alternative solution of both the first and second stages is also proposed, based on the provisions of the oriented graph theory, in which each proposal of the applicant from the whole their total number \( P=\{ P_1, P_2, ..., P_n \} \) is considered with point of view of the existence of some nomenclature of general parameters \( S=\{ S_1, S_2, ..., S_m \} \), concretizing the strategic goal. Accordingly, when changing such a goal, the set of common parameters (properties) can also
change.

The parameters of the proposals of the applicants considered in various degrees contribute to the achievement of the goal, and therefore have an unequal importance (weight). At the same time, each parameter of applicants is developed with varying intensity.

Taking into account the above, the solution of the task will be the identification of the applicant, whose proposal is most conducive to achieving the goal. Within the framework of the solution, it is possible to single out the following stages.

The first stage is the detailed description of the task, its representation in the form of a hierarchy, that is, a partially ordered set.

The second stage involves solving two subtasks:

1. Determination of the intensity of manifestation of parameters for each proposal (importance of a particular parameter);
2. Determination of parameter importance (weight) relating to tender goal.

Identification of importance assumes:

1. Pairwise comparison of proposals from the point of view of the intensity of manifestation of the given parameter in them;
2. Pairwise comparisons of parameters relative to their importance in achieving the goal of the competition.

To verify the pairwise comparison of applicants (parameters), a quantitative scale is required. The quantitative estimates of pairwise comparisons determined on this scale are described by a matrix of order $n \times m$:

$$A = a_{i,j}, (i, j = 1, 2, ..., n)$$

Elements $a_{i,j}$ identify rules [2]:

1. If $a_{i,j} = \alpha$, then $a_{j,i} = 1/\alpha$, under condition $\alpha \neq 0, \alpha \in \{1, 2, ..., 9\}$;
2. If evaluation of parameter intensity in proposal $P_i$ is the same as $P_j$, then $a_{i,j} = a_{j,i} = 1$, in particular, $a_{i,i} = 1$ for all $i$.

After verifying quantitative evaluation among all pairs $P_i, P_j$ of parameter intensity manifestation through $a_{i,j}$, the task is to determine for each applicant $P_i$ the weight $w_i$ of a particular proposal in the context of this parameter.

Thus, the solution of such a task is to establish the vector of the matrix of pairwise comparisons, according to the maximum value

$$A \cdot W = \lambda_{max} \cdot W, W = (w_1, w_2, ..., w_n)^T,$$

where $T$ – sign of transposing.

For a normal solution we assume $\alpha = w_i + ... + w_n$ and replace the vectors $W$ by $(1/\alpha)W$. The resulting gradient will be taken as $W$, which guarantees the uniqueness of the weight vector $W$, as well as the legitimacy of the assumption $\alpha = w_i + ... + w_n$.

By analogy, the weights of the parameters for the given target are identified as a matrix of pairwise parameter comparisons, and we establish the maximal eigenvector with its further normalization.

The final stage is the identification of the applicant, whose proposal maximizes the achievement of the goal. To do this, weights of proposals relative to the goal are established and the candidate’s proposal that has the maximum weight is selected, the mathematical definition of this statement looks like this:

$$W = [W_1W_2...W_n]W_p,$$

where

$W_i = (w_{i1}, w_{i2}, ..., w_{in})^T$ – weight vector of proposals according to $i$ parameter,

$n$ – number of proposals, $i= 1, 2, ..., m$, $m$ – number of parameters,
\[ W_p = (w_1^p, w_2^p, \ldots, w_n^p)^T \] – weight vector of parameters relative to target.

In terms of this task, such indicators as the approval index and the hierarchy consistency ratio can be identified and used in decision making as a supplement.

5. Conclusions

Formulated on the basis of the theoretical foundations and methodological principles for the formation of a parametric model for selecting contractors under the conditions of an engineering management scheme, the recommendations can promote: effective use of limited resources; their orientation to the fullest satisfaction of the needs of the construction industry; increasing the competitiveness of construction organizations. Also, as promising areas for further scientific research, it is possible to specify:

1. Methodological foundations determining the order of relationships between parties and participants of investment activity under the conditions of engineering scheme management at all stages from construction to facility commissioning in the context of procurement activities.
2. Development of an information and analytical model aimed at solving the tasks of organizing and conducting contract auctions, including specific tasks by the participants of tenders.
3. Improvement of the scientific and methodological basis for the procedure for evaluating and selecting proposals of developers and contractors based on the use of objective and reliable information, competitiveness data of the applicants, allowing to evaluate objectively the potential capabilities of offerors.

Acknowledgments

This work was financially supported by Ministry of Education and Science of the Russian Federation (#NSh-3492.2018.8).

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