

Evaluation and improvement of the reliability of organizational structures of ICP by the method of hierarchy analysis

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Abstract.

Subject of study: The subject of the study is process of formation of organizational structures of investment and construction projects (ICP) from elements with a high level of its own reliability.

Objectives: The aim of the study is to create the methodological foundations for designing and building the organizational structures of the ICP from the elements (ICP participants) with a sufficient level of reliability.

Materials and methods: Based on the study of the existing practice of analyzing and forecasting the performance of companies and corporations in various sectors of the economy in Russia and the World, when solving the tasks of selecting ICP casual participants from a possible list of candidates, it seems promising to use such a mathematical tool of the system approach to solving complex decision-making problems as the Hierarchy Analysis Method (HAM).

Results: The lack of objectivity existing in the adaptation of the applied methodologies and methods of assessing the indicators of consistency (sustainability, reliability, competitiveness, liquidity of assets) of organizations to the analysis of the activity of enterprises in the construction sector, as well as the disproportional weighting of computational models by indices of unusual construction organizations of nature can be partially compensated by transforming the process of determining the reliability of enterprises that are elements of the organizational structure of the ICP, the multi-criteria choice problem, solved by the hierarchy analysis method.

Conclusions: Integration into the process of designing the organizational structures of the ICP of the existing experience in solving probabilistic decision making problems by the method of hierarchy analysis can be used as the basis for increasing the level of ICP reliability by forming the organizational structures of the ICP from highly reliable elements.

1. Introduction

The implementation of any investment and construction project (ICP) is currently accompanied by the need to carry out a set of works to select potential project participants based on the assessment of a large number of indicators of their activities.



Regional and national standards often regulate the processes of selecting a potential counterparty, however, according to the experience of the last ten years, these methods do not show their effectiveness in domestic practice.

In most cases, the ineffectiveness of competitive procedures for selecting ICP participants is manifested in the inability of the contractor to fulfill its obligations at the required level of quality, with compliance to previously approved deadlines and the estimated cost of work.

The result of using imperfect procedures of organizational design determines the impossibility of successful implementation of the ICP with the achievement of its key indicators, reducing its profitability. At present, large-scale investment projects in the field of nuclear energy, which provide for a multi-level interconnection of organizational, technological and organizational-logistical processes, distributed among various participants of the ICP, demonstrate the urgent need to improve the efficiency of organizational design procedures [1].

This need substantially increases as the project becomes more complex and in some cases is conditioned by technological features of the project implementation. In terms of the nuclear industry, such a technological aspect may be the volume and degree of pre-assembly of building structures and equipment, as well as the full-scale application of the hybrid-block method of structural elements and equipment of nuclear power plants [2].

Research work in the field of studying methods to improve the efficiency of the implementation of investment and construction projects is based on the application of a systematic approach, which in turn is an integral tool for system engineering of construction [3] – scientific and technical discipline that studies technical, organizational, managerial building systems and intersystem connections, mutually contributing to the achievement of the final result in construction.

The system-technical approach in this case allows to present the organizational structure of the ICP as a system formed from elements with different levels of their own reliability. In this case, it is logical to assume that an increase in the efficiency of the implementation of the ICP is possible due to the formation of the organizational structures of the ICP from elements with a high level of its own reliability [4].

2. Literature Review

Historically, in determining the probability of the construction system achieving the planned result of the operation, the researchers turned to the apparatus of organizational and technological reliability (OTR) [5]. Presenting the organizational structure of the ICP as a system is the absence of complete failures in its work inherent in technical systems, however, in the operation of such a system, there are failures, necessarily affects the effectiveness of achieving this goal. In the process of its development, the approach to assessing the reliability of construction production through the apparatus of organizational and technological reliability has developed.

A significant contribution to the development of the OTR apparatus was made by representatives of the scientific school of the Moscow State University of Civil Engineering, professors: A A Gusakov, A V Ginzburg, A A Lapidus, A A Morozenko.

Professor A A Gusakov, in the framework of the OTR assessment, considered simulation and graphic modeling of building systems, discussed the issues of organizational and technological design and computerization of the evaluation of investment projects and their manufacturability [6].

Professor A V Ginzburg studied: OTR duration of construction, OTR of material and technical support of construction, OTR value indicators of construction.

Also, an estimation of the OTR cost parameters of construction and the development of a system for the automation of design of the OTR for the functioning of construction organizations [7]. In his studies, A V Ginzburg paid special attention to the study of the interrelations between the OTR indicators in various areas of the functioning of construction organizations-three subsystems: the subsystems for scheduling the construction industry, the subsystems for the material and technical support of construction [8], subsystem of production and financial indicators (budget calculations).

Professor A A Lapidus thoroughly studied the system-technical basis for automating the design of organizational structures for large-scale construction. In his studies, it was proposed to use the author's apparatus for a comprehensive assessment of the effectiveness of work performance and management of the project - organizational and technological and integrated potential (OTP) [9]:

- The organizational and technological indicator (potential) of the production of individual building structures (roofing, enclosing structures);
- OTP of the construction project;
- potential of efficiency of organizational and technological solutions of a construction object;
- integral potential of efficiency of organizational-technological and administrative decisions of a building object.

In the works of Professor A A Morozenko studied the conditions for the formation of reliable organizational structures. The characteristics of organizational structures of enterprises such as flexibility and sustainability were singled out and studied in detail [10], the information-resource modeling of the sustainability of the organizational structure of the ICP and the functional modeling of the life cycle of investment-construction projects with a reflex-adaptive organizational structure [11].

An important result of the scientific work of Professor A A Morozenko can be considered a proposal on the possibility of increasing the efficiency of organizational and projected structures and the life cycle of investment-building projects on the basis of a reflex-adaptive paradigm.

It should be noted that in the process of studying various aspects of the OTR, questions of reliability evaluation of the elements of the organizational structure of construction projects are untouched [12]. Therefore, relying on the accumulated experience, continuing research in the field of organizational and technological reliability, it seems reasonable and innovative to pay special attention to assessing the reliability of participants in investment and construction projects as elements of the organizational structure.

Thus, it becomes possible to create a universal tool that allows you to perform a comprehensive analysis of potential project participants at the design stage of the ICP organizational structure (OS) and generate the ICP OS solely from elements with a high level of reliability.

3. Materials and methods

Continuing research in the field of integrated assessment of the reliability of enterprises expected to participate in the implementation of ICP, it seems logical to study in depth the influence of system (internal) factors of reliability of the functioning of the organizational structure of the enterprise.

Within the framework of the study of the most significant factors of the activity of enterprises and organizations of the construction industry, we decided to use the formed list of system factors classified into 4 groups [12]:

1. Factors characterizing the organizational structure of the enterprise;
2. Factors reflecting the industrial and technological level of development and equipping the enterprise;
3. Factors of the financial and economic state of the enterprise;
4. Factors of social and labor conditions of functioning of the enterprise.

Conceptually, the reliability of the potential ICP participant can be assessed on the basis of a deep analysis of the activity of the selected enterprise in the established time period. In this case, one of the stages of analysis will be the search and determination of the relative values of the factors of the activity of the enterprise.

Taking in the calculations that the reliability of the enterprise will be determined by the aggregate of the values of the factors of different groups, it should be stipulated that this statement will be absolutely true only in case when weight factors are calculated and proposed for each group of factors that vary depending on conditions, specifics, profile activities of the company and its place in the organizational structure of the ICP. For example, it is obvious that the impact of the indicator of the financial and economic group of factors on the reliability of the enterprise will be different in

determining the reliability of the project organization that performs work under the contract of work and, for example, the investment company investing resources in the implementation of the ICP.

For the purpose of visualizing the level of reliability of the enterprises under consideration, let us turn to the concept of the reliability coefficient of an organization (enterprise), for the calculation of which we use the following formula:

$$K_{p_n} = \sum_{m=1}^{m=4} [\mu_m * \frac{\sum_{k=1}^{k=l_m} T_n(k_m)}{l_m}], \text{ where:} \quad (1)$$

K_{p_n} – coefficient of reliability n-th organization from the list of potential participants of the ICP;

n – the ordinal number of the organization (enterprise) from the list of potential participants of the ICP;

μ_m – weight factor of the m-th group of system factors;

$T_n(k_m)$ – the relative value of the k-th factor of the m-th group, calculated for the n-th enterprise;

l_m – the total number of factors in the m-th group;

m – ordinal number of the group of system factors;

k – the ordinal number of factor in the m-th group;

Obtaining a relative value of the factor of reliability of the enterprise is possible by comparing the absolute value of this factor for the enterprise under study with the industry average.

$$T_n(k_m) = \frac{T_{\text{абс.}}^n(k_m)}{T_{\text{ср. стр.}}^n(k_m)}, \text{ where:} \quad (2)$$

$T_{\text{абс.}}^n(k_m)$ – the absolute value of the k-th factor of the m-th group, calculated for the n-th enterprise by investigating the effectiveness of its functioning in the established time period;

$T_{\text{ср. стр.}}^n(k_m)$ – the generalized average industry-wide value of the k-th factor of the m-th group, determined on the basis of analysis of the data of state statistical observations.

An objective source of the average statistical values of the factors of activity of organizations and enterprises can be considered officially published materials of the Federal State Statistics Service of Russian Federation (Russtat) [13, 14]. Collected and analyzed data on the activities of companies of a specific subject of the Russian Federation or the industry as a whole are regularly published in statistical compilations, such as:

- «Russian Statistical Yearbook»;
- Statistical compilation "Construction in Russia";
- Statistical Digest "Labor and Employment in Russia";
- Statistical Digest "Russia in Figures";
- Statistical compilation "Labor force, employment and unemployment in Russia";
- Statistical Digest "Finances of Russia" and others.

Also, a large number of selected industry and regional publications of the Federal State Statistics Service, containing the relevant for this study, comparative statistical information.

Having determined the sources and methods of calculating the values of the factors of the activity of organizations, the question arises of determining the weight characteristics of the four semantic groups of factors [15]. This task can be interpreted as a multicriterion choice problem and assume as an instrument of its solution such an instrument of the system approach as the method of hierarchy analysis (MHA) [16].

The hierarchy analysis method was developed in 1970 in the US by Thomas L Saati. Since then, this method has found wide application not only in many areas of the science of technology, but also in public and corporate governance. Advantages of this method are considered to be its high versatility and simplicity of structuring a complex decision-making problem in the form of a hierarchy. The method of analyzing hierarchies is one of the most common methods of decision making in investment

and construction activities, successfully combining the formalization and transparency of procedures used with the reliability of the result obtained.[17]

The sequence of solving the task posed by the hierarchy analysis method involves performing the following steps:

1. Definition of the problem. Goal setting;
2. Selection of the main criteria and alternatives;
3. Building a hierarchy tree (from the goal through the criteria to the alternatives);
4. Construction of a matrix of pairwise comparison of criteria for the goal and alternatives according to the criteria;
5. Analysis of the obtained matrices;
6. Determination of the weights of alternatives in the hierarchy system.

The purpose of the work in this case is to select from the potential pool of enterprises the most reliable for its subsequent integration into the organizational structure of the ICP.

As criteria, it is logical to select groups of systemic factors:

- Criterion # 1 - Organizational structure of the enterprise
- Criterion # 2 - Industrial and technological level of equipping the enterprise
- Criterion # 3 - Financial and economic state of the enterprise
- Criterion # 4 - Social and labor conditions of the enterprise

Thus, the hierarchy tree will have the following form (Figure 1).

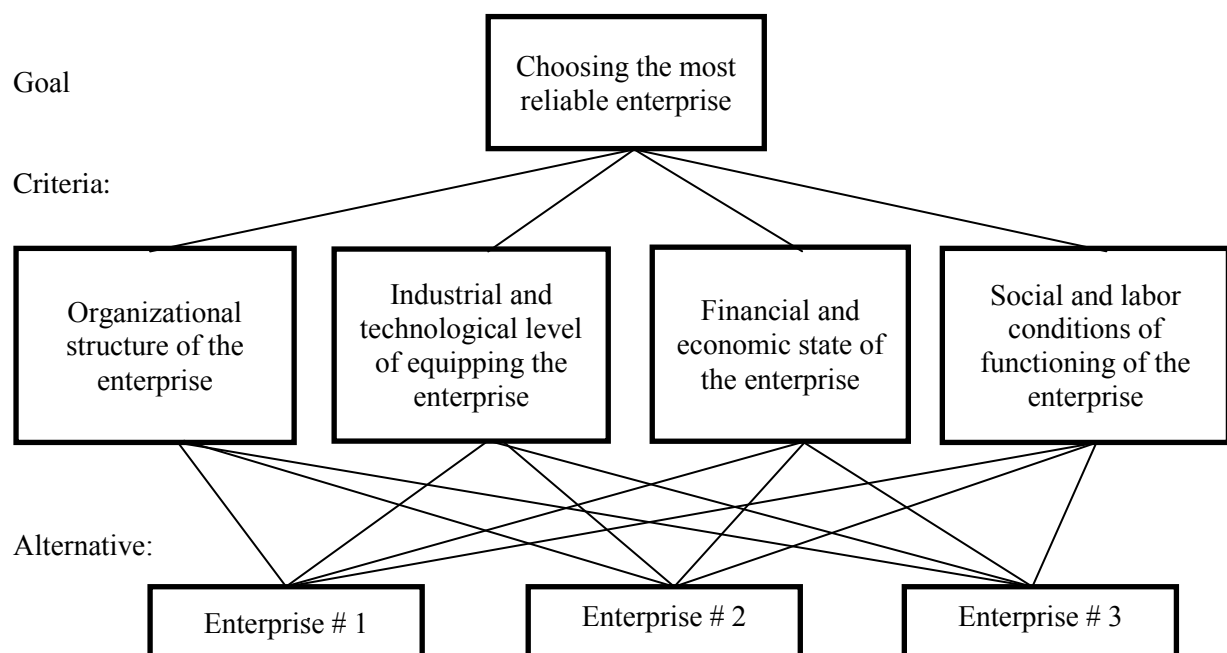


Figure 1. The hierarchy tree of the most reliable enterprise choice

Having completed the construction of the hierarchy tree, it is necessary to establish the priorities of the criteria and to evaluate each of the alternatives according to the criteria. In the MHA, the elements are compared in pairs depending on the degree of their influence [18], this comparison is made on the basis of a scale of relative importance (Table 1)

Table 1. Scale of relative importance judgments

Importance	Intensity of relative importance (direct value)	Intensity of relative importance (reverse value)
Equal importance	1	1
Moderate superiority of one over the other	3	1/3
Substantial superiority	5	1/5
Significant superiority	7	1/7
Very strong superiority	9	1/9
Intermediate solutions between two adjacent judgments	2,4,6,8	1/2, 1/4, 1/6, 1/8,

In order to perform calculations to determine the reliability factor of an enterprise with maximum objectivity, it is necessary to involve in the peer comparison of the criteria of representatives of the expert community having the required level of professional competence and disinterested in obtaining any particular result.

The data obtained from the experts (Table 2) of a pairwise comparison is made up in the form of a matrix. The presence in our case of four criteria determines the dimensionality of the matrix 4 x 4.

Table 2. Pairwise comparison of alternatives by purpose

Goal - identify the most reliable enterprise	Organizational structure	Production and technological level	Financial and economic condition	Social and labor conditions
Organizational structure	a_{11}	a_{12}	a_{13}	a_{14}
Production and technological level	a_{21}	a_{22}	a_{23}	a_{24}
Financial and economic condition	a_{31}	a_{32}	a_{33}	a_{34}
Social and labor conditions	a_{41}	a_{42}	a_{43}	a_{44}

a_{ij} – the relative importance of the i-th criterion with respect to the j-th

a_{ji} – relative importance of the j-th criterion in relation to the i-th (the inverse a_{ij})

In addition, it should be noted that the desired matrix is inversely symmetric, i.e. It holds property: $a_{ij} = 1/a_{ji}$. Due to this circumstance, it is possible to present it in the following form (Figure 2)

$$\begin{vmatrix} a_{11} & a_{12} & a_{13} & a_{14} \\ 1/a_{12} & a_{22} & a_{23} & a_{24} \\ 1/a_{13} & 1/a_{23} & a_{33} & a_{34} \\ 1/a_{14} & 1/a_{24} & 1/a_{34} & a_{44} \end{vmatrix}$$

Figure 2. Matrix of paired comparisons of alternatives for the purpose

Having carried out a pairwise comparison of the criteria for the goal, it is necessary to compare the alternatives according to the criteria. In this case, we will deal with four matrices (Table 3 (a), (b), (c), (d)) according to the number of criteria originally chosen.

Table 3. Pairwise comparison of alternatives according to the criteria:

(a) Criterion No. 1 - Organizational structure of the enterprise,

(b) Criterion No. 2 - Industrial and technological level of equipping the enterprise,

(c) Criterion No. 3 - Financial and economic status,

(d) Criterion No. 4 - Social and labor conditions of the enterprise

(a)

Criterion No. 1 - Organizational structure of the enterprise	Enterprise # 1	Enterprise # 2	Enterprise # 3
Enterprise # 1	b_{11}	b_{12}	b_{13}
Enterprise # 2	b_{21}	b_{22}	b_{23}
Enterprise # 3	b_{31}	b_{32}	b_{33}

(b)

Criterion No. 2 - Industrial and technological level of equipping the enterprise	Enterprise # 1	Enterprise # 2	Enterprise # 3
Enterprise # 1	c_{11}	c_{12}	c_{13}
Enterprise # 2	c_{21}	c_{22}	c_{23}
Enterprise # 3	c_{31}	c_{32}	c_{33}

(c)

Criterion No. 3 - Financial and economic status	Enterprise # 1	Enterprise # 2	Enterprise # 3
Enterprise # 1	d_{11}	d_{12}	d_{13}
Enterprise # 2	d_{21}	d_{22}	d_{23}
Enterprise # 3	d_{31}	d_{32}	d_{33}

(d)

Criterion No. 4 - Social and labor conditions of the enterprise	Enterprise # 1	Enterprise # 2	Enterprise # 3
Enterprise # 1	f_{11}	f_{12}	f_{13}
Enterprise # 2	f_{21}	f_{22}	f_{23}
Enterprise # 3	f_{31}	f_{32}	f_{33}

Due to the fact that the MHA is suitable both for comparing factors for which only judgments are possible (in our case, criteria for the goal) and for factors on which it is possible to perform their quantitative comparison (alternatives according to the criteria) [19], we do not need to apply to the expert community for a paired comparison of alternatives according to the criteria. Instead, it is possible to use the relative values of the indicators of certain performance factors of two different enterprises.

In that case b_{ij} , c_{ij} , d_{ij} , f_{ij} —the values of matrices of paired comparisons of alternatives according to the criteria, defined as the ratio of the arithmetic mean of the relative indices of the enterprise's activity factors of the m -th group, calculated for the i -th enterprise to the analogous value of the j -th enterprise.

$$b_{ij} = \frac{\sum_{k=1}^{k=lm} T_i(k_m)}{l_m} * \frac{l_m}{\sum_{k=1}^{k=lm} T_j(k_m)} = \sum_{k=1}^{k=lm} \frac{T_i(k_m)}{T_j(k_m)} \quad (3)$$

The next step is to verify the completed calculation by checking the consistency of local priorities. In the MHA, to accomplish this task, it is provided that the consistency index is found and the consistency relation [20]. The valid value of the consistency index is defined for each particular size of the matrix. When this indicator is found within the established limits, a transition to the synthesis of alternatives.

At this stage, priority vectors are calculated, which allow us to determine the priorities of alternatives [21]. These values in our case will be the reliability coefficients of the enterprises under study.

Having determined the priorities of the alternatives, we can arrange them in descending order, thereby highlighting among the enterprises studied, the enterprise with the highest and lowest level of reliability.

4. Conclusion

Use to determine the level of reliability of ICP participants as elements of the organizational structure of the author's method, providing for a comprehensive analysis of performance indicators of potential enterprises participating in the ICP, compared with industry average values calculated and officially published by the Federal Service for State Statistics of the Russian Federation, followed by the application of the hierarchy analysis method characterized by high universality and objectivity of the computations produced, is to ensure the formation of organizational structures ICP cells with maximum reliability level. This circumstance will certainly affect the level of reliability of the organizational structure of the ICP as a whole, which in the future will ensure an increase in the efficiency of its implementation.

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