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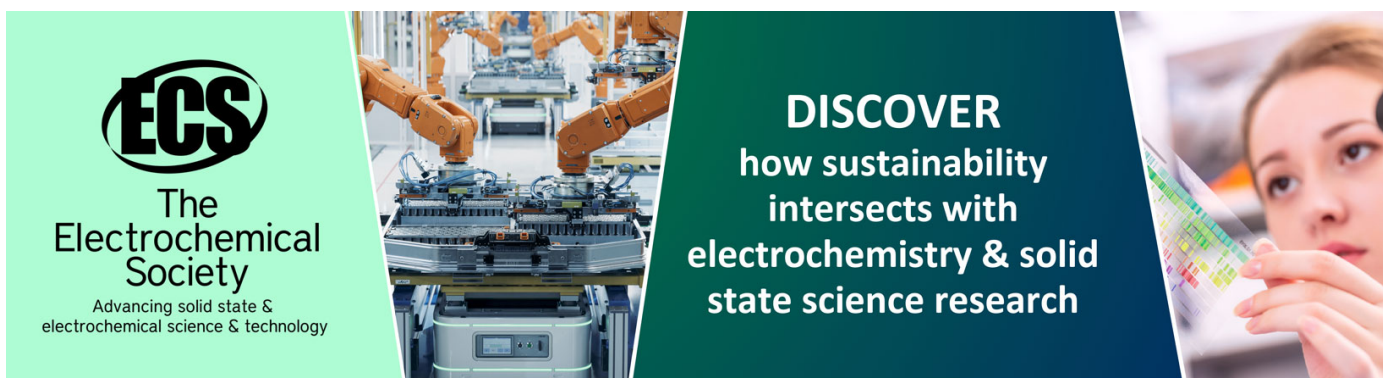
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Modern methods for evaluating the technical and organizational-technological solutions for repair and construction production

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Abstract. The paper deals with the problems of evaluating technical and organizational-technological solutions for repair and construction production at various stages. The choice of materials and technological options is carried out using the principles of consistency and complexity. The developed system for identifying the options makes it possible to describe in general terms any technical and organizational-technological solutions for the production of repair and construction works used in the overhaul practice, and those that will appear as the repair and construction industry develops. The work defines a scientifically based formalized set of indicators describing the methods compared versions of technical, organizational and technological solutions for the production of repair and construction works during capital repairs. The effectiveness of the developed method is confirmed by the representativeness of the research results carried out on the example of the production of works on the insulation of external walls during the apartment buildings overhaul.

Introduction

The construction industry in Russia today is surviving one of the most difficult periods in its history. After a record volume of housing construction, a decline began, and the positive dynamics of investments and commissioning of objects is observed due to the repair and construction production in the housing and utilities complex (hereinafter HUC) [1].

The growth in the volume of repair and construction production in the housing and utilities sector is due to significant changes in the housing code of the Russian Federation (hereinafter the RF housing estate) in terms of the organization of the overhaul system (hereinafter OS) of common property in apartment buildings (hereafter ABP). Overhaul today is the most ambitious housing renovation project in the history of the country.

The increase in the volume of repair and construction work (hereinafter PCW) is also due to the priority project "Urban Environment" implementation. The Ministry of Construction of the Russian Federation approved the passport of the priority project "Formation of a comfortable urban environment" with the aim of providing financial support to the subjects of the Russian Federation for the improvement projects implementation. Within the framework of the project, works are being carried out on the improvement of courtyards and public spaces.



It is necessary to take into account that these projects are long-term in nature, for example, the overhaul programs are designed for 35 years (2014–2049), and the “City Environment” for 5 years (2017–2022). Thus, today the RCW market is promising and quite attractive for business. The attractiveness of this market is due to its size and growth potential, as well as its social role.

According to these programs, co-financing is carried out at the expense of subsidies from the federal budget and the funds of the owners, which imposes additional requirements for the rational use of funds. The use of funds in practice should be highly efficient and should be subject to economy. Compliance with these principles allows to create great opportunities for the rational, careful and efficient use of funds and at the same time the timely performance of works of the required quality.

Based on the analysis of the results of previous studies, scientific papers, as well as the current regulatory, instructional and methodological documentation, a number of unresolved issues have been identified. This paper is devoted to solving a set of tasks aimed at developing fundamentally new methods for evaluating technical, organizational and technological solutions (hereafter TOTS) of repair and construction production (hereinafter referred to as RCP). To this end, a number of studies speeding up the design and preparation of the ESP and improve the quality of decisions made have been carried out. Effective and informed decisions can be made only on the basis of the TOTS evaluation, taking into account the analysis of previously applied design solutions [2], determining the main directions for developing new and further comprehensive improvement of existing TOTS.

The urgency and lack of development of these problems determined the choice of the topic and the direction of the present study. The main goal of this work is to analyze the principles of TOTS assessment for the RCP and to develop an algorithm for solving problems of this type.

Materials and research methods

The prospects for the development of the RCW in the sphere of housing and communal services (hereinafter HCS) and the urban environment require making high-quality decisions related to the choice of organizational and technology assessment methods for implementing programs in the housing and utilities sector. The choice of evaluation methods can be carried out only by means of efficiency criteria — mathematical values that allow:

- to determine the measure of compliance with the results of the goal;
- to find quantitative bases for decision-making not only in conditions when the environment is completely clear (deterministic tasks), but also in conditions of uncertainty, when probabilistic assessment of various factors is required (stochastic problems);
- to use computers to solve problems, which allows you to quickly get the most informed solutions.

The analysis carried out in this paper suggests that it is necessary to determine the criteria for choosing decisions at various stages of preparation of the RCP in the housing and utilities sector and the urban environment (hereinafter referred to as UE).

To develop the conceptual framework for TOTS at various stages of preparation of the RCP in the housing and utilities sector and the UE it is necessary to:

- To determine the main indicators of the efficiency of TOTS repair and construction production;
- to develop methods for the synthesis of TOTS for the implementation of RCW programs; suggest ways to account for information uncertainty in multi-purpose assessment of options.

To solve the set tasks, it is necessary to study the main features of planning and implementation of programs in the housing and utilities sector and the UE, analyze the existing design methods and evaluate organizational and technological solutions, and determine the basis for choosing the technologies of the RCW in the housing and utilities sector and the UE.

As a result of studying the main features of planning and implementing programs in the housing and utilities sector and the UE, it was found that there are requirements for the development and implementation of the regional OS programs. For the planning and organization of multi-apartment

buildings in OS, in each constituent entity of the Russian Federation a regional common property OS program has been developed in the ABP, which can be adjusted once a year.

The regional program of the common property in the ABP defines deadlines for the repair work. The order of holding the common property OS in the ABP in the regional program of the OS is determined on the basis of the following criteria:

deterioration of the general property of the ABP, determined according to the results of the ABP technical condition monitoring;

commissioning year ABP;

date and type of the ABP general property last OS;

The presence of a threat to the safety of life and health of citizens.

The cost of services and (or) work on the OS common property in the ABP, which can be paid by the regional operator at the expense of the OS Fund, formed on the basis of the minimum contribution of the common property to the OS to the ABP, should be no more than the amount of the established marginal cost of services and (or) work on the OS. The size of marginal costs by the type of work is recommended to be developed on the basis of the principles of unification of the accepted nomenclature of capital construction objects, structural elements of buildings and structures and complexes of work performed, accepted units of measurement.

Each subject of the Russian Federation sets the size of the marginal value independently. The most difficult issue in calculating the marginal cost for the implementation of the regional program of the OS is the lack of a reference and information base that allows reliably calculating the necessary funding for certain types of work, depending on the type of ABP.

From the above-mentioned, it is clear that when planning a regional program of the OS it is necessary to solve the classical problem of choosing the technology of work and, as a result, the allocation of resources. Allocating resources between jobs is required in such a way as to minimize the expected costs (production costs). The classic solution to this problem (as applied to the planning of regional programs of the OS) is the selection of such TOTS for each ABP in order to carry out the task with minimal cost.

Starting to solve the resource allocation problem when planning the OS regional programs, it is necessary to proceed from the fact that the complexity of the multi-purpose choice lies primarily in the contradictory criteria. Hence the need to apply a certain scheme of a reasonable compromise [3], which allows to improve the quality of the decision taken on all criteria is performance indicators.

At the first stage of the study, a system was proposed for determining the variants of TOTS of RCW production in the OS.

Variations of TOTS production of RCW in the OS are designed to select the most rational (optimal) for specific production conditions. TOTS production of RCW is disclosed by many components:

$$MP = \{O, M, T, M_e\}, \quad (1)$$

where O - is the possible solutions for the organization of the PSC; M – is the possible solutions for the mechanization of the RCW; T – is the possible solutions for RCW production technology; M_e – is the possible solutions for the RCP management.

Decisions on the organization of the RCP in the OS are expressed as:

$$O = \{X_1, X_2, \dots, X_n\}, \quad (2)$$

where $X_1 = \{X_{11} \cup X_{12}\}^*$ (* symbol $\cup$ means an alternative).

At:

$$\begin{aligned} X_{11(12)} &= \{x_{13} \cup x_{14} \cup x_{15}\}; \\ X_2 &= \{x_{21} \cup x_{22}, \dots, \cup x_{2...}\}; \end{aligned}$$

$$X_n = \{x_{n1} \cup x_{n2}, \cup \dots, \cup x_{n...}\}. \quad (3)$$

The solutions on the mechanization of the RCP in the OS is determined as

$$M = \{Y_i\}; M = \{Y_1 \cup Y_2, \dots \cup Y_5\}, \quad (4)$$

Where

$$\begin{aligned} Y_1 &= \{y_{1i1}, \cup y_{1i2}, \dots, \cup y_{1i...}\}; \\ Y_2 &= \{y_{2i1}, \cup y_{2i2}, \dots, \cup y_{2i...}\}; \\ Y_5 &= \{y_{5i1}, \cup y_{5i2}, \dots, \cup y_{5i...}\}; \end{aligned} \quad (5)$$

at $i = 1, 2, \dots, m$.

The solutions for RCW production technology in the OS are expressed as

$$T = \{Z_1, Z_2, \dots, Z_n\}, \quad (6)$$

Where

$$\begin{aligned} Z_1 &= \{Z_{1i1}, \cup Z_{1i2}, \dots, \cup Z_{1i...}\}; \\ Z_2 &= \{Z_{2i1}, \cup Z_{2i2}, \dots, \cup Z_{2i...}\}; \\ Z_m &= \{Z_{mi1}, \cup Z_{mi2}, \dots, \cup Z_{mi...}\}; \end{aligned} \quad (7)$$

at $i = 1, 2, \dots, C$.

The management solutions for RCP in the OS are expressed as

$$M_e = \{R_1, R_2, \dots, R_n\}, \quad (8)$$

Where

$$\begin{aligned} R_1 &= \{r_{11}, \cup r_{12}, \dots, \cup r_{1...}\}; \\ R_2 &= \{r_{21}, \cup r_{22}, \dots, \cup r_{2...}\}; \\ R_n &= \{r_{n1}, \cup r_{n2}, \dots, \cup r_{n...}\}; \end{aligned} \quad (9)$$

Giving the restrictions on the components $\{O, M, T, Me\}$ TOTS of RCW production in the OS in the expanded form can be represented as follows:

$$MP = \left(\begin{array}{l} X_i (at x_{11} - x_{15}), X_2 (at x_{21} - x_{23}), X_3 (at x_{31} - x_{33}), X_4 (at x_{41} - x_{42}) \\ Y_i (at Y_1 = (y_{11...} y_{15...}) \div Y_3 (y_{31...} y_{32...})) \\ Z_i (at z_{111} - z_{15...}), Z_2 (at z_{211} - z_{23...}), Z_3 (at z_{311} - z_{34...}), Z_4 (at z_{411} - z_{43...}) \\ R_1 (at r_{111} - r_{15...}), R_2 (at r_{211} - r_{24...}) \end{array} \right) \quad (10)$$

The developed system of identifying options allows to describe in general terms any TOTS production of RCW used in the practice of the OS, and those that will appear as the RCP develops. In this view, each method of production of RCW in the OS is uniquely characterized and can be indicated by letters or numbers.

At the second stage, a set of indicators is defined describing the RCW production methods in the OS describing the compared versions of the TOTS methods.

The final decision when choosing the option TOTS method of production of RCW in the OS is made after comparison. Justification options associated with a comprehensive analysis of their main components, which directly or indirectly affect the performance indicators.

The following indicators are often used as indicators for evaluating options for TOTS of the RCW production method in the OS: total amount of work; the number of machine-shift work of the assembly mechanism; total labor intensity; production per worker per shift; average number of workers; the total cost of operating machinery; the same per unit of work; consumption of the base material; the duration of the work; reduction of the duration of work; labor productivity growth; estimated cost; economic effect, etc.

When comparing the options for TOTS of the RCW production method in the OS, it is important to deal with the contradictory assessment indicators characterizing the options under consideration, and the contradictions between them can be either strict or not strict. [4].

At the same time, one of the tasks solved in the course of research was the definition of a scientifically grounded formalized set of indicators describing the compared versions of the TOTS methods of RCW production in the OS.

The solution of the problem was carried out by the expert assessments method. The prioritization of the estimated indicators characterizing the compared versions of the TOTS production methods for RCW production in the OS was carried out by the method of generalized ranking, which is that the estimated indicators are ranked by the values of the ranks obtained by each indicator from all experts participating in the assessment [5].

Experts were offered the following indicators: total amount of work; total labor intensity; output per worker per shift; the total cost of operating machinery; the duration of the work; labor productivity growth; estimated cost; economic effect. As a result of the assessment, the indicators characterizing the duration, labor intensity and estimated cost of work were selected.

At the third stage, an algorithm was developed for evaluating TOTS for the RCW of compared variants.

The end result of the assessment should be the choice of one or another solution, which is advisable to carry out using one of the known optimization methods [6,7,8].

Indicators of laboriousness, cost and duration of work depend on several independent variables (factors), therefore, to solve this problem, it is necessary to move from a discrete statement of the problem to a dynamic model that takes into account the change in the performance of each TIR for RCW as a function.

If the process of changing the indicators of each TOTS for RCW describes some function of many variables and it is necessary to find such a value at which it takes an extreme value (minimum or maximum), then it is necessary to solve the problem of finding an extreme value (optimization). For the solution, the method of unconditional optimization is used - the method of gradient descent.

The process of finding the optimal solution consists of k iterations and ends when the condition is met, as in the case of coordinate-wise descent $\max |z_{i+1} - z_i| \leq \varepsilon$.

At the selected point of the initial approximation, the iteration sequence will be:

$$\bar{z}_{k+1} = \bar{z}_k - \lambda_k \text{grad}(G(\bar{z}_k)), \quad k = 0, 1, 2, \dots, m. \quad (11)$$

The λ_k pitch is selected based on the use of one-dimensional optimization methods. The value of λ_k is sufficiently small, and in this case the condition: $F(\bar{z}_{k+1}) \leq F(\bar{z}_k)$

The iterative process can be considered complete if the function values in the subsequent steps remain unchanged.

As a rule, using gradient optimization methods, the minimum of a smooth function is found much faster, convergence is observed faster.

The task of finding the minimum indicators of the complexity, cost and duration of work for each TOTS, quite correctly can be solved by the presented method.

For clarity, the possibility of using the developed methodology for assessing TOTS for RCW carried out the formulation and development of methods for solving practical problems in the OS ABP.

A production test of the developed method reliability and the obtained research results representativeness confirmation was carried out on the example of the production of works on the weatherization of the external walls of the ABP.

To select the TOTS option for weatherizing the external walls of the ABP, the following types of technologies are considered: ventilated facades with a hinged protective lining; plastering systems for facades; spraying effective insulation compounds (various types of polyurethane foam).

Further, the work identified possible solutions for the organization, mechanization, technology and management, and formed the options for TOTS of RCW production methods in the OS on wall insulation. The obtained versions of the TOTS of RCW production methods for wall insulation were identical for all types of technologies. Variability was observed when choosing solutions for the organization and production technology of RCW for wall insulation. Solutions were observed:

1. by organization - O, in terms of changing the direction of development of the process (flow) - X_1 :

vertical - x_{13} ;

horizontal - x_{14} ;

2. by technology - T, in terms of the use of scaffolding - Z_1 :

inventory tubular scaffolding - z_{111} ;

towers - z_{112} .

As a result of the verification calculations, it was found that the technological scheme of work from inventory tubular scaffolding is the most rational in the production of thermal insulation works on extended (in plan) buildings up to 20 m high, as the total estimated cost is reduced to 5%, by reducing the cost 10% of works and 8% of unrecorded works in the total cost structure. Reduction of labor intensity up to 15% and duration by 12%.

The technological scheme of work from mounted cradles is advisable when working on non-stretched (in plan), as a rule, single-section buildings of increased number of storeys, as well as on non-typical buildings with a large number of projecting parts (elevator shafts, bay windows, etc.). When choosing this technological scheme, the total estimated cost is reduced to 7%, by reducing the cost of work by 12% and unrecorded work by 10% in the total cost structure. Reduction of labor intensity up to 20% and duration by 15%.

In each case, the technological scheme of the production of works on the weatherization of the external walls of the ABP is effective, at which the duration, laboriousness and cost of the work package will be minimal. Thus, the application of the obtained calculation results makes it possible to evaluate TOTS when weatherizing ABPs at the design stage for the main organizational and technological indicators (labor intensity, duration of work, estimated cost of work) depending on the goal (in this work the goal was to minimize all types of costs).

Summary

As a result of the study, the theoretical aspects of the solution of the TOTS assessment task for RCW and the principles of forming a system for determining the TOTS options for the production of RCW were formulated and considered; the main evaluation indicators scientifically substantiate the options and factors influencing them, and also proposed an algorithm for evaluating the compared versions of the TOTS production of works during the ABP overhaul.

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