Introduction of innovative technical solutions in construction on the basis of the concept of engineering

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Abstract. Introduction of innovative technical solutions in construction is an important element in improving the competitiveness of construction companies. The main impediments to the introduction of innovations in construction were defined. The concept of engineering in construction is disclosed, and a possibility of using it as a development instrument in construction to solve the actual problem related to increasing the operating efficiency of construction process participants was analysed. The purpose of the article is to define a mechanism for the assessment of the effectiveness of innovative technical solutions introduction in construction on the basis of the concept of engineering. The article uses data on the results of the research in the area of studying of modern innovative solutions in construction conducted in 2017. Over 50 solutions were analysed, including new and improved building materials, constructions, technological solutions, modern solutions in the area of building engineering systems. A comparative express analysis of traditional and innovative solutions by qualitative characteristics, novelty and efficiency was carried out. The results of the study made it possible to define a set of basic options for effectiveness evaluation for different types of innovative technical solutions in construction, including local solutions and complex ones that can have a significant impact on the effectiveness of a construction project as a whole. A mechanism for the selection of innovative technical solutions in construction on the basis of developed criteria for an effective engineering solution was proposed. The necessity of assessing the efficiency of innovative technical solutions in construction at all stages of the life cycle of a piece of property considering the total cost of ownership was substantiated. Principal directions for the integration of engineering instruments into the activities of development companies in construction were proposed.

1. Introduction

In modern economic conditions the problem number one is to ensure the competitiveness of construction companies [1, 2]. This applies to all participants of the investment and construction sector - from manufacturers of building materials to contractors and developers responsible for the final result of construction projects implementation. The most important issue in increasing the competitive advantage is introduction of innovative solutions in the construction sector [3-5]. At the same time innovations can be divided into two types by nature: these are technical innovations [6, 7] and innovations in the area of final product value. Technical innovations include production of new or improved building materials, use of modern machinery and mechanisms in the construction process, introduction of new technologies in construction. In turn, value innovation is a specific type of
innovation [8-10], which development is based on the Blue Ocean Strategy concept and involves creation of new value and utility to the consumer, sometimes without introduction of significant technological innovations. This concept is used in various fields of activity, including construction. As examples of value innovation one can mention projects in the area of residential real estate [11, 12], including SMART housing [13] implemented in the Russian Federation. Since technical and technological aspects of new solutions in construction are primarily considered within the framework of this article, the first type of innovation was chosen as the subject of research.

Considering the process of construction from the point of view of a developer, one should note the relevance of principles of green [14, 15] and sustainable [16-18] construction. The main elements of the concept of sustainable construction are presented in Figure 1.

![Figure 1. The concept of sustainable construction](image)

In order to follow the principles of sustainable construction to the fullest extent and ensure competitiveness in the long run, developers need to work over three elements of effectiveness: cost, construction project implementation time and the quality of products (finished construction project). Introduction of technological innovation, as previously noted, is a tool for competitiveness provision, which helps improving one or more elements of effectiveness, as is the case with additive technologies [19, 20], under certain conditions, reduce construction time and simultaneously reduce construction costs.

It should be noted that the main obstacles to the introduction of technical innovation solutions in construction are as follows:

- An increased level of risk and uncertainty when working with innovative technologies.
- Lack of necessary experience of investment and construction process participants (designers, general contractors, subcontractors, etc.) when working with an innovative solution.
- Complexity of assessment of the effectiveness of innovative technical solutions, especially in conditions of insufficient initial data for the calculation.
- In a number of cases there are problems of underdevelopment of innovative solutions introduced into mass production, which causes their low quality and inefficiency.
- High cost of innovative solutions at the initial stages of introduction into production.

To overcome these obstacles and ensure a more reasonable assessment of the effectiveness of innovative technical solutions, it is proposed to use engineering tools. The concept of engineering is considered in this paper as a conceptual approach, on which developer's activities should be based. The purpose of the article is to form a mechanism for the assessment of the effectiveness of innovative technical solutions introduction in construction on the basis of the concept of engineering.

2. Materials and methods

The methodological base of the research is presented by methods of scientific analysis and synthesis, qualitative and quantitative analysis, includes statistical processing of the data used. To assess the effectiveness of innovative solutions, we used comparative analysis, tools for technical and economic analysis and investment evaluation.

The research is based on the use of the concept of engineering. When it comes to the concept of engineering, it is widely used in various sectors: power engineering, machine building, chemical industry, high technologies. The methodology and engineering tools are actively used in the construction industry. However, the concept of engineering is rather blurry. It can include various types of activities in the area of construction: civil engineering, engineering construction [21, 22], re-engineering construction [23, 24]. The term of engineering can also be used to refer to various job profiles, such as, a construction engineer and a civil engineer.

Within the framework of this paper engineering is considered as a more global conceptual model, an activity aimed at an increase in the effectiveness of implementation of projects in the area of construction based on introduction of optimal innovative solutions. In turn, the concept of engineering takes into account main provisions of lean construction, value management in construction and effective quality management in construction.

For the purposes of correct assessment of the effectiveness of technical solutions, it is proposed to use the model of the overall life cycle of the facility, which includes the pre-investment and investment stages, the operation stage followed by subsequent reproduction and/or utilization of the item of immovable property.

Criteria for the selection of an effective technical innovation solution (K1, K2, K3) presented on Figure 2.

Based on the identified criteria research work on the collection and systematization of information about innovative technical solutions in the area of construction, implemented or planned to be implemented in Russia was carried out in 2017. New or improved building materials and structures, equipment, construction technologies were considered as solutions. In total, 56 innovative solutions in construction were considered, which correspond to the preliminary analysis, criteria of novelty and quality. As sources of initial information mainly secondary data were used for the research: information provided by developers of innovative solutions and, if available, reviews of such solutions in scientific and technical publications, as well as testimonials of construction companies having experience of working with data technology solutions. As a result, taking into account available initial data for each innovation, a rapid analysis of their efficiency was carried out in comparison with conventional technical solutions. The aim of the research was to systematize information on innovative solutions in construction and justification of the general methodological approach to the assessment of the effectiveness of introduction of innovative technical solutions in construction on the basis of the concept of engineering.
Figure 2. Criteria for the selection of an effective technical innovation solution

3. Results
Types of considered innovative solutions are presented in Table 1.

| Type of innovation          | Number of solutions, pcs | Share of effective solutions, % |
|-----------------------------|--------------------------|---------------------------------|
| Thermal insulation materials| 12                       | 91.7                            |
| Glazing with special properties | 10                  | 80.0                            |
| Waterproofing materials     | 8                        | 100.0                           |
| Sound insulation materials  | 5                        | 100.0                           |
| Construction materials      | 5                        | 100.0                           |
| Engineering equipment       | 6                        | 100.0                           |
| Technological solutions     | 2                        | 100.0                           |
| Integrated solutions        | 8                        | 100.0                           |

The effectiveness of an innovative solution was considered in relation to the implementation of a particular building solution, and this solution was considered effective if the final result from introduction in accordance (1) (c) exceeded zero (for all solutions, except integrated ones). Integrated solutions are solutions that presupposed introduction of a set of innovations (a minimum of three) within the framework of one construction project, while the total costs for these solutions amounted to at least 15% of the total investment budget of the project. In this case, effective solution were solutions
that ensured an increase in the net present value (NPV) relative to the option without applying innovations.

Then, all considered effective innovations, except integrated ones, were combined into one group - local innovative solutions. The impact of all solutions - both local and integrated - on project NVP was assessed, and standard deviation as well as error margin for the confidence level of 95% were calculated. The results are presented in Table 2.

Table 2. Efficiency of innovative solutions

| Group of innovations | Number of solutions | $\frac{dNPV}{NPV}$, % | Standard deviation (S) | Limit of error |
|----------------------|---------------------|-----------------------|------------------------|----------------|
| Local                | 45                  | 0.23                  | 0.15                   | 0.04           |
| Integrated           | 8                   | 2.03                  | 0.41                   | 0.29           |

In spite of the fact that sampling for integrated innovative solutions was small, it can be concluded that it is reasonable to assess these solutions by changes in economic efficiency indicators, such as NVP, internal rate of return (IRR), payback period (PP) and profitability index (PI), provided that they make a substantive contribution to the investment value of the project. In general, the following conditions (2) shall be fulfilled when calculating all these indicators:

$$
\begin{align*}
    dNPV &= (NPV_{inn} - NPV_{tr}) > 0 \\
    dIRR &= (IRR_{inn} - IRR_{tr}) > 0 \\
    dPP &= (PP_{inn} - PP_{tr}) < 0 \\
    dPI &= (PI_{inn} - PI_{tr}) > 0
\end{align*}
$$

(1)

Where: indicators followed by $inn$ are calculated for the construction project taking into account an integrated innovative solution.

indicators followed by $tr$ - without this solution, using traditional materials, constructive, technological solutions, machinery and mechanisms.

When conducting a rapid assessment, it is possible to use one of the above indicators (usually IRR or NPV).

The following expression presented in its general form (3) should be used for local innovative solutions:

$$
E_1 = dI + dC + A = \left( \frac{I_{tr}}{t_{tr}} - \frac{I_{inn}}{t_{inn}} \right) + \left( C_{tr} - C_{inn} \right) + A
$$

(2)

Where: $E_1$ is the overall economic effect from the implementation of the innovative solution (rubles per 1 year of the planned life cycle of the innovative solution).

$dI$ is a change in specific investment costs when implementing the innovative solution (rubles per 1 year of the planned life cycle of the innovative solution).

$dC$ is a change in annual costs associated with the operation and maintenance of the innovative solution during its implementation (rubles per 1 year of the planned life cycle of the innovative solution).

$I_{tr}$ is costs at the investment stage associated with the implementation of the traditional solution (rubles).

$t_{tr}$ is the life of the traditional solution (years).

$I_{inn}$ is costs at the investment stage associated with the implementation of the innovative solution (rubles).

$t_{inn}$ is the life of the innovative solution (years).
$C_r$ is annual costs associated with the operation and maintenance of the traditional solution (rubles per 1 year of the planned life of the traditional solution).

$C_{inn}$ is annual costs associated with the operation and maintenance of the innovative solution (rubles per 1 year of the planned life of the traditional solution).

$A$ is additional annual benefits (if any) associated with the introduction of technical innovation (rubles per 1 year of the planned life cycle of the innovative solution).

When $E_1 > 0$, we can talk about the expediency of implementation of the innovative solution. It should be borne in mind, however, that the expression (2) can be transformed as follows (3) for solutions associated with the use of innovative machinery and mechanisms at the construction phase, new technological solutions, where there is no effect at the operational stage:

$$E_2 = dI + dT$$

Where $E_2$ is the overall economic effect from the implementation of the innovative solution (rubles).

$dI$ is a relative change (decrease) in investment costs when implementing the innovative solution (rubles).

$dT$ is an additional effect associated with the reduction in the duration of the investment project, if any (rubles). This effect can be indicatively calculated by means of saving funds allocated to servicing debt financing of construction (rubles).

In some cases introduction of an innovative solution can be feasible even if $E_1 < 0$. Typically, this refers to a situation when an increase in costs (both investment and operational) is accompanied by a more significant increase in qualitative characteristics of a construction object, and this increase is critical from the point of view of the developer and owner of the object. This applies particularly to specialized real estate, infrastructure facilities and facilities, to which heightened requirements for security provision are imposed, such as nuclear power plants.

In this case, to evaluate the feasibility of implementation of an engineering solution, the following formula (4) can be used:

$$K_e = \frac{dQ}{dZ}$$

Where $K_e$ is an indicator of the effectiveness of the engineering solution.

$dQ$ is an increase in the integral performance index in case of implementation of the innovative solution (in %, can be calculated on the basis of expert estimates).

$dZ$ is an increase in the total unit costs for the implementation of the engineering solution, including investment and operational costs per 1 year of the planned life cycle of the innovative solution.

Value $K_e > 1$ is the condition for the expediency.

Based on the results obtained, a generalized mechanism to evaluate the effectiveness of implementation of innovative technical solutions in construction on the basis of concept engineering was proposed. The algorithm of assessment carried out at the level of the project developer is shown in Figure 3.
Figure 3. Assessment of the effectiveness of innovative technical solutions

4. Conclusions
The obtained results can be used by development companies within the framework of justification of the effectiveness of the innovative solutions used. The proposed mechanism for rapid assessment of the effectiveness of innovative technical solutions in construction allows integrating engineering tools into development and, in the long term, result in increased competitiveness.

It should be noted, however, that the solutions proposed in the paper require additional elaboration and refinement. In particular, the task related to the assessment of the effectiveness of innovative solutions at different stages of the life cycle of the innovation solution including an analysis of possible risks and opportunities is in priority. On the one hand, introduction of the most advanced and promising developments in the area of construction can create additional competitive advantages for the participants of the investment and construction process. On the other hand, qualitative and reasoned initial data for the qualitative assessment of the effectiveness of proposed solutions are usually missing at early stages of an innovation life cycle.

It should also be taken into account that introduction of technical innovations is an important but not the only one tool to ensure competitiveness in construction. Within the framework of this article, other aspects of increasing the effectiveness of development activities, such as value innovation, HR management, GR (government relations) and other management tools in the investment and construction sphere were not considered.

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