Effectiveness of using BIM in construction: comparative analysis and evaluation methodology

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Abstract. The paper focuses on investigating methods to improve the integration of Building Information Modeling (BIM) in the construction sector with the aim of enhancing the efficiency of executing investment and construction projects. The relevance is caused by the complexity of calculating the economic effect in the short-term planning period when implementing investment and construction projects using BIM and, accordingly, the lack of methods for economic justification of the need and possibility of using BIM at the design and construction stages. The study aims to compare modern software products and establish a methodology for evaluating the effectiveness of utilizing BIM in investment and construction projects (ICP). This methodology will facilitate conducting an economic analysis to justify the integration of these technologies in project implementation. The study concluded with an examination of global implementation practices, identification of challenges in BIM utilization, a survey of software alternatives, and an assessment of current approaches for economically justifying the adoption of BIM throughout various stages of the ICP life cycle.

The research is based on systemic, process and situational approaches, methods of comparative and factor analysis, as well as methods of economic-mathematical and graphical modeling.

1 Introduction

Building Information Modeling (BIM) technologies are gradually but steadily entering the global construction industry, displacing traditional approaches to planning and construction management. Modern reality imposes new, previously unimposed requirements for the design of construction projects. In contemporary construction management, it is essential to have not just a project plan for a facility but also its information model. This model encompasses all the vital information needed for the entire lifespan of the investment and construction project [1, 2].

Over the course of its existence, the traditional approach to design processes with performing analytical calculations and issuing a set of drawings and specifications based on...
CAD design has accumulated quite a lot of shortcomings that can be easily solved with the help of BIM. The development of a digital information model using BIM can reduce construction duration and increase the economic efficiency of creating complex construction projects. Solutions based on a digital information model provide determination of estimated costs, control of construction processes, identification of inconsistencies in the project, exchange of information between participants in an investment and construction project, as well as planning and optimization of construction processes, which leads to a reduction in material consumption costs, increased productivity and cost reduction at all stages of the life cycle of investment and construction projects [3].

Activation of BIM implementation processes in the construction industry depends on the ability to assess the economic effect of using BIM at the main stages of the ICP life cycle. Unfortunately, existing methods for calculating the economic effect in construction do not take into account the specifics of the industry and are not adapted to the conditions for using BIM [4]. Therefore, an urgent goal of working to accelerate the implementation of BIM in the construction industry is to develop a methodology for selecting BIM options based on calculating the efficiency indicators of using information modeling technology at the main stages of the ICP life cycle.

2 Materials and Methods

In today's market, there is a wide range of software products available for implementing a BIM project in the investment and construction sector. These software tools are utilized at different stages of the project life cycle. The majority of leading software systems have demonstrated their effectiveness through successful applications across various segments of the global construction industry [5].

To initiate the evaluation of software products for a BIM project, the first step is to outline a set of tasks (referred to as BIM tasks) that cover all phases of the project life cycle. These tasks establish the groundwork for incorporating BIM into an investment and construction project and serve as the foundation for BIM project planning.

To identify problems solved using BIM tools, methodological recommendations “The BIM Project Execution Planning Guide” (The Pennsylvania State University) were developed in the USA. This document formulates 25 primary and secondary tasks of using BIM with a step-by-step algorithm for their implementation [6].

BIM tasks are divided into main and additional (subtasks). Table 1 presents a list of the main BIM tasks for each stage of the life cycle of an investment and construction project in accordance with the current level of BIM use in the construction industry [7].

Table 1. List of main BIM tasks tied to the life cycle stages of an investment and construction project.
In global practice, the listed information modeling tasks are called BIM Uses. The options for using BIM Uses are different: from using BIM to solve one problem at one stage and ending with the integrated use of BIM Uses throughout the entire life cycle of an investment and construction project. For example, in some cases, an information model is created to calculate the scope of work and obtain estimates, and in other cases, to coordinate participants in an investment and construction project [8].

In order to assess the variability of choice, Table 2 presents the software products available on the market and used in information modeling in the context of the ICP life cycle.

Table 2. Software for information modeling in the context of the ICP life cycle.
An analysis of Table 2 shows that to solve all of the listed tasks (even within one stage) of information modeling, a certain set of several software products, and also different development companies, is required.

The analysis of software products for information modeling of investment and construction processes shows that in the context of many software options and BIM Uses, it is quite difficult and almost impossible to assess the effectiveness of BIM implementation in investment and construction projects. Therefore, to solve this research problem, a decomposition of the investment and construction project is carried out and the effectiveness of using BIM at the design stage is considered to solve the main problem of using information modeling in the Russian construction industry – the release of design and working documentation [9].

At the current time, most companies in the Russian investment and construction industry are actively using BIM to solve this problem when designing construction projects. As part of this study, an analysis is carried out of the two most popular software packages used by domestic companies at the design stage: Revit and Renga.

Since the Renga and Revit software packages discussed above most fully comply with the requirements of the current level of BIM development in the domestic construction industry, then a detailed analysis of these software products will be carried out, on the basis of which the criteria for assessing the effectiveness and selection of a software package for an investment and construction project using BIM will be determined [9].

### 3 Results

As part of this study, a comparative analysis of software options used at the design stage for an investment and construction project implemented using BIM is carried out, taking into account the current level of implementation of information modeling in the construction industry.

The comparative analysis is carried out taking into account the requirements and limitations of information modeling software when choosing the BIM option for a specific investment and construction project.

Table 3 presents a comparative analysis of three software packages (Revit, Renga and NanoCAD) taking into account the requirements of regulatory documents in accordance with the current level of BIM implementation in the Russian construction industry.

<table>
<thead>
<tr>
<th>Software requirements for BIM modeling of a specific ICP</th>
<th>Revit</th>
<th>Renga</th>
<th>NanoCAD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Availability of a shared data environment</td>
<td>X</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>Possibility of using the open IFC data exchange format</td>
<td>О*</td>
<td>О**</td>
<td>О**</td>
</tr>
<tr>
<td>Possibility of collaboration of all related specialists on a single information model</td>
<td>X</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>Possibility to check design solutions and information model</td>
<td>О**</td>
<td>О**</td>
<td>О**</td>
</tr>
</tbody>
</table>

* X – used at the life cycle stage, O – not used at the life cycle stage.
X – software compliance with requirements, O – software non-compliance with requirements
*
- the RVT format is used with subsequent conversion to the RVT format.
**
- additional software is required to meet these requirements.

The Revit software package is one of the first platforms in the field of BIM design. In Revit, the design of the structural part (metal structures and reinforced concrete products) is implemented at a high level based on the construction of a digital analytical model. Revit's engineering capabilities are less advanced, limiting full calculations and the creation of information dependent on engineering system calculations. The popularity of the Revit software platform is caused by the presence of a convenient interface and a large database of families, which are ready-made objects and elements.

Fig. 1. Algorithm for developing a methodology for calculating the economic effect of using BIM in a specific project.
Today, one of the main factors that makes it difficult to assess the effectiveness of using BIM in investment and construction projects is the availability of different options for the software used. Therefore, it is proposed to evaluate the effectiveness of BIM implementation in ICP using a new methodology based on an algorithm for selecting software for a specific ICP, presented in Figure 1, taking into account the current level of using BIM in the Russian construction industry.

The algorithm presented in Figure 1 provides for assessing the effectiveness of using BIM in a specific ICP at the construction stage, which is especially important for assessing the economic effect of using BIM in ICP obtained in the short-term planning period.

According to the presented algorithm, at the first stage, an analysis of the currently available methods for assessing the effectiveness of BIM is carried out, taking into account the application in a specific ICP.

Next, at the second stage, indicators are determined on the basis of which the economic efficiency of using special software for information modeling in a specific ICP is calculated.

The effectiveness of BIM implementation primarily depends on the following factors:

\[ \Delta S - \text{reduction in construction costs (expenses)} \]

\[ \Delta T - \text{reduction of construction duration} \]

\[ \Delta m - \text{improving the quality of design documentation “approved for construction”} \]

The dependence of the effectiveness of BIM implementation in specific ICPs on the factors listed above can be represented as a function:

\[ E_{BIM} = f(\Delta S, \Delta T, \Delta m) \]

The obtained calculation results are analyzed in order to make a decision on the need to use specialized software for BIM modeling in a specific ICP or to use a traditional approach using CAD design. At the final stage, software is selected to create an information model of the construction site in a specific ICP.
4 Discussion

After analyzing the global utilization of BIM in the investment and construction sector, it was found that the Russian construction industry significantly lags behind developed foreign countries that are leading in the adoption of BIM in the investment and construction processes. This lag behind foreign countries is primarily due to the inability to assess the economic effect in the short-term planning period, because there is no methodology that allows assessing the effectiveness of BIM application at the construction stage.

The research suggests a step-by-step algorithm for creating a local methodology to evaluate the efficiency of BIM usage in investment and construction projects within the unique context of Russia. The algorithm contains seven main stages that take into account the regulatory framework of the Russian Federation and options for the possible use of software available on the Russian market for ICP implemented using BIM.

5 Conclusion

Following the evaluation of software for BIM in the ICP sector, a comprehensive list of software systems utilized for information modeling in construction projects was created. A comparative analysis was conducted based on a tailored model for selecting software to be employed during the design phase. An algorithm for selecting software for ICP implemented using BIM has also been developed, which is based on an economic and mathematical model for calculating the economic effect resulting from a reduction in construction costs.

The developed methodology for assessing the effectiveness of BIM application is based on the calculation of cost reduction for the semi-variable part of overhead costs due to a reduction in construction duration and the magnitude of the reduction in direct costs as a result of increasing the accuracy of construction cost calculations. Because the use of BIM entails an increase in design costs (by almost 20%), the total economic effect is calculated as the difference between the reduction in construction costs and the increase in design costs.

References

