Assessment of effectiveness of implementation of BIM technology in the system of an organization management on the example of an energy efficiency formula

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Abstract. This article examines the degree of study of the methodological foundations of BIM technology. A generalization of the BIM technology features for the main stages of the life cycle is given. The aspects of information modeling (BIM) technology implementation are considered. One of the possible methods for evaluating the decision effectiveness in the process of introducing BIM technology is proposed using the energy efficiency formula as an example.

1 Introduction

We live in the era of digital transformation. Thus the vast majority of construction or transport organizations in Russia resort to use the modern information technologies. This, in turn, improves the efficiency and effectiveness of their activity.

Nowadays, companies increasingly turn to the information modeling technology. This technology allows not only to improve the quality of the final product, but also to analyze data on the current and future stage of the production.

Information modeling technology originated in the first half of the twentieth century. Patrick J. Henretti, Douglas Engelbart, Christopher Alexander, Ivan Sutherland, Charles Eastman and others were the first scientists who started to investigate it. [2] This technology has gone from analog computing stage to the system for managing the information about the objects. This technology has application advantages in practice.

Nevertheless the process of implementation of information modeling technology into the company’s activity is slow despite its advantages.

This article reveals the reasons that delay the introduction of Information modeling technology into the Russian companies’ activity. It also reveals ways of adoption an effective and correct decision in the process of technology implementation in Russia.

This article has the following purposes:
1. To evaluate the level of knowledge about the introduction of information modeling technology.

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2. To consider the way to assess the profitability, efficiency and correctness of the decision made in the process of implementation BIM-technology using the energy efficiency formula as an example.

2 The main part

First of all, it is necessary to determine what is known about the basic foundations of BIM technology.

What does the “information modeling technology in construction” means? It means the creation of a detailed model (a virtual prototype of a structure), each element of which is endowed with certain technical properties. This helps to identify possible errors before the start of construction and operation. As a result, this leads to an increase in the profitability of the construction process. [1]

In other words, building information modeling technology (or BIM technology) is the process of creating and using information about an object with the ability to manage the object throughout its life cycle.

The basic principles of BIM technology were investigated by foreign and national researchers.

So, Antonyuk A.A., Chizhov S.V. identified such principles as: an infrastructure principle (it means the process of association the stages of development of the territory to increase the functional value and consumer qualities of the structure), a closed-loop principle (it means that the process of creating a spatial information model of an object is closed), an economic principle (it means the impact of cost estimation in long-term planning). [3]

While Talapov V.V. and others consider that BIM technology is based on a principle of a single model (it means the consistency of the information about the model), a principle of pragmatism (it means that companies apply to the modeling process each time when it is necessary to achieve the objectives), a principle of sequential modeling (it means a unified approach to the project as a whole). [4 - 5]

Each of the principles not only do not contradict each other, but also complement each other, creating a more firm basis for the process of information modeling application.

Many researchers note the benefits of introducing of BIM-technology in their writings.

For instance, R. Sacks, L. Koskela, B. Dave and R. Owen believe that BIM-technology can increase labor productivity, reduce non-production costs and minimize activity that does not create added value. It is worth noting that the authors also consider BIM technology in conjunction with the “Lean construction”. [6, 10]

P. Oskouie, D.J. Gerber, T. Alves and B. Becerik-Gerber pointed out that BIM-technologies can provide effective control over object’s life cycle, facilitate and accelerate the construction process and improve the maintainability of buildings using information about building structures. [7]

Kozlov A.D., Kozlova A.S., Telyatnikova N.A. identified 7 advantages of BIM technology in comparison with the classical model of development and implementation of a construction project: a quality (a design reliability, accurate and consistent data), a project implementation time (an optimization of construction stages), a risk reduction, a budget (an optimization of life cycle costs), a work safety, a communication system (an open exchange of information between participants in construction process), a simple decision making (an easy analysis of a potential infrastructure problem area).[8]

Mustafin N.Sh., Baryshnikov A.A., Spryzhkov, A.M. identified the following advantages: a reduction of construction time, a reduction of the cost of the project, an identification of potential errors at the design stage, scheduling benefits, benefits in budgeting and a modern facility management. [9]
It is worth noting that most authors give a theoretical basis for the application of BIM-technology and its benefits. However, in the vast majority, there is no data on practical applicability.

It is necessary to generalize the characteristics of BIM technology for the main stages of object’s life cycle, taking into account a wide range of researchers’ opinions (table 1).

Table 1. Characteristics of information modeling technology.

<table>
<thead>
<tr>
<th>№</th>
<th>Stage of object’s lifecycle</th>
<th>Characteristics of BIM-technology</th>
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<tbody>
<tr>
<td>1</td>
<td>Project concept</td>
<td>A justification of investments with high accuracy of study; opportunity to choose the most profitable project.</td>
</tr>
<tr>
<td>2</td>
<td>Design</td>
<td>A reduce project cost through minimizing errors. - An improvement of designers’ labor productivity.</td>
</tr>
<tr>
<td>3</td>
<td>Construction</td>
<td>An improvement of construction companies’ labor productivity. - A reduction of construction time. - A transparency in production by facilitating the process of control and verification.</td>
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<tr>
<td>4</td>
<td>Operation</td>
<td>An optimization of servicing costs by using the information about building structures, its operation and maintenance. - Profitability in the preparation of estimates and consideration of risks.</td>
</tr>
<tr>
<td>5</td>
<td>Demolition (dismantling)</td>
<td>A site preparation for new construction. - A safety of works during the dismantling of objects - A possibility of reusing secondary waste.</td>
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</table>

However, numerous projects over the past two decades have clearly shown that the simple implementation of BIM technologies does not guarantee success. Moreover, the results vary depending on how and by whom these technologies are implemented.

Ghang Lee, André Borrmann, Trivedi G., Trivedi V., Succar B., Kassem M. consider that in the process of adoption of a new technology, the people and the process are often recognized as the essential factors in addition to technology itself. This concept is referred to as the people, process, and technology framework. [11 - 14]

Numerous national and foreign researchers identified the main problems in the implementation of BIM technology. They could be divided into two groups:

1. BIM processes.

   According to many authors, the advantage of BIM-technology is the saving of budget and time for design. However, Lee G., Park H.K., Won J., Leite F. note that, firstly, the introduction of BIM technologies is an expensive process, and, secondly, models with a higher level of detail require more time spent on design. [15 - 16]

   Jang S., Lee G., Kim J.W. considered various strategies for managing a BIM project. They learned how a contractual sequence can change the involvement attitude of BIM project participants in design coordination and value engineering during the preconstruction activities and eventually impact the cost of the project. [17 - 18] It has been understood that a partial standardization of BIM processes is required to realize efficient BIM project management.

2. BIM people.

   The problem of people is often recognized as the most difficult obstacle to the implementation of BIM-technology.

   Lee G. notices that during BIM adoption, the “Dunning Kruger Effect” is often observed (engineers may be overconfident of their cognitive ability to check and find errors before construction). At the same time, the ability to use BIM tools is regarded as the fundamental skill of BIM users.
Thus, Sacks R. believes that the lack of experts in the field of BIM-technologies and the lack of structured training programs in universities is a major problem. [22]

The same disadvantages are noted by national authors, such as Petrov K.S., Kuzmina V.A., Fedorova K.V., Dronov D.S., Kimetova N.R., Tkachenkova V.P. and others [19 - 20]. They describe the following problems of implementation and application of BIM-technology in Russia:

− companies have lack of interest in BIM implementation. Many companies seek to save existing work practices.
− lack of qualified specialists. Students still study 2D design at universities.
− software errors.
− expensive software. Nowadays the cost of licenses varies from one hundred thousand to one million rubles.
− lack of standardization of BIM technology at the federal level.

Certainly, new technologies are usually face with the different obstacles. However, if we know the problem, it becomes easier to find a solution.

The article presents the author's vision of evaluating the effectiveness of technology implementation in the organization's management system according to the methodological foundations of BIM technology and to the problems of its implementation.

Based on the above, it is necessary to notice main aims of BIM technology. There are an increase of labor productivity, a reduction in non-production costs and a minimization of work that does not create added value. The main task of BIM technology is to minimize the losses that occur in the case of irrational organization of the production process of construction products both at the stage of the construction of the object, and at the stages of its design and maintenance. [1]

The assessment of profitability, efficiency and correctness of the made decision (both for the introduction of BIM-technology in general, and for a specific stage of object’s life cycle) can be conditionally represented as an energy efficiency formula:

\[
\text{Energy efficiency} = \frac{\text{Result}}{\text{Resource costs}}
\]  

(1)

The “result” means the consumer effect from the introduction of BIM-technology. In other words, it is the transformation of resources into a product or service. The “resource costs” (labor and energy) mean resources that produced in order to obtain an effect. For convenience, the indicators can be presented in value form. [23]

The process of achieving the goal has different expenses or energy costs. The minimum of such costs means the maximum of energy efficiency for a particular stage of object’s life cycle or production stage. The cost minimization formula becomes the most important for decision making:

\[
\text{Labor} + \text{Energy} \Rightarrow \min
\]  

(2)

The indicator of efficiency (savings) can be represented as the difference in resource costs (labor and energy) with the same consumer effect in each of the options for implementing the technology.

In other words, the formula allows you to evaluate and choose the most effective way to implement BIM-technology by assessing the possible costs (losses) expressed in terms of value. [23]

\[
\text{Saving} = (\text{Labor}_i + \text{Energy}_i) - (\text{Labor}_{i+1} + \text{Energy}_{i+1})
\]  

(3)

The indicators “i, i + 1” mean number of resource costs (possible costs) in the compared options of BIM implementation.
Thus, the presented method allows to:
1. Analyze the existing approach to the process of implementation and use of BIM technology.
2. Assess the predictive risks, effectiveness and efficiency of the implementation of BIM technology.
3. Take corrective actions to minimize losses arising from the irrational organization of the production process of construction products.

3 Conclusion

Foreign and national studies have shown that interest in BIM technologies is growing despite the problems and difficulties associated with their implementation. Each study not only does not contradict each other, but also complements each other creating a more solid foundation for the application of BIM-technology.

The experience of the last two decades has shown that the simple introduction of BIM technology does not guarantee its effect. An integrated approach is needed when implementing a new technology. Also it is important to pay special attention not only to technology, but to the people involved in the process and the production process.

Currently, there are many different ways of implement technology. However, some of these ways become unsuccessful due to the wrong decision made at the initial stage of implementation. Energy efficiency is one of the possible methods for evaluating the effectiveness of the implementation of BIM technology. It is necessary to minimize risks. This approach is taken from the heat-and-power industry and can be similarly applied to assess the efficiency of a company's production in any other field of knowledge.

Eventually BIM technologies will replace the familiar and traditional methods of 2D design. In the future, companies will overwhelmingly use information modeling technology as the primary tool.

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