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APPLICATION OF BIM TECHNOLOGIES IN CONSTRUCTION PROJECT MANAGEMENT

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Abstract:
The article discusses the prospects for using building information modeling (BIM) technologies in the context of construction project management. An analysis of the benefits provided by BIM at various stages of the life cycle of a construction project is conducted, and potential barriers and risks associated with the implementation of this technology are identified. Examples of successful integration of BIM into project management practice are presented. The role of BIM in ensuring increased transparency, efficiency and sustainability of the construction industry is emphasized.

Keywords: BIM, construction project management, digitalization, information modeling, building life cycle.

Introduction

The scientific novelty of the article lies in the integrated approach to the study of the application of BIM technologies in the management of construction projects. Unlike existing works, which usually focus on the technical aspects of building information modeling, the presented study considers BIM as an effective management tool covering the stages of planning, coordination, monitoring and operation of a construction site. For the first time, a systemic analysis of key barriers and problems hindering the implementation of BIM in the construction industry is carried out, with an emphasis on institutional, organizational and personnel limitations. Examples of successful implementation of BIM projects in international practice are presented, which made it possible to substantiate the practical value of this technology in real construction conditions. Thus, this work contributes to the scientific and practical understanding of BIM as a management

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platform capable of ensuring the digital transformation of the construction industry.

Traditionally, the construction industry is characterized by conservatism in terms of innovation. However, in the context of the digital transformation of the economy, modern information technologies are becoming increasingly important, as they can significantly improve the efficiency of project management. One of the key technologies that determines the process of digitalization of construction is Building Information Modeling (BIM) - the technology of information modeling of buildings. BIM is not just a three-dimensional model of an object, but a digital twin containing comprehensive information about the object throughout its entire life cycle.

The purpose of this study is to determine the potential for using BIM technologies in construction project management, analyze the benefits provided by this technology, and identify the limitations and problems that arise during its implementation.

Building Information Modeling (BIM) technology is an innovative approach to the processes of design, construction, operation and dismantling of capital construction projects, based on the use of a unified digital information model. A BIM model is not only a three-dimensional visualization of an object, but also a multi-layer database containing geometric, functional, cost and operational information about the object at all stages of its life cycle.

According to the definition adopted by the US National Institute of Standards and Technology (NIST), BIM is a “digital representation of the physical and functional characteristics of an object that serves as a single source of information for all project participants” [1].

The key feature of BIM is the integration of all processes related to the life cycle of a construction project into a single digital environment. This ensures the possibility of effective interaction between all project participants, including architects, engineers, customers, contractors, suppliers and operating organizations, within a single information space.

The constituent elements of BIM include:

- 3D - three-dimensional geometric model;
- 4D - modeling of project time parameters (construction schedule management);

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- 5D - modeling of cost indicators;
- 6D - assessment of energy efficiency and sustainability;
- 7D - management of operation and maintenance of the facility [2].

Practical application of BIM allows: to identify and eliminate design conflicts at early design stages; automate the processes of calculating the volume of work and drawing up estimate documentation; improve the accuracy of calendar and resource planning; control changes and versioning of documentation in real time [3].

Thus, BIM technologies transform the construction management paradigm, replacing the linear and fragmented interaction scheme with an integrated lifecycle management system for an object, aimed at increasing the efficiency, transparency and sustainability of the construction process.

Building information modeling (BIM) has a significant impact on all stages of construction project management, from the conceptualization stage to the operational stage. By integrating all design data into a single information model, BIM helps to improve planning accuracy, control efficiency and coherence of interaction between project participants.

At the initial design stage, BIM allows you to form a conceptual model of the object, evaluate various design scenarios and predict potential risks. By using 3D modeling and conducting simulation analysis, it is possible to identify problem areas in advance, determine optimal solutions regarding the location of the facility, design features and cost. The use of BIM at this stage improves the validity of investment decisions, facilitates effective management decisions and reduces the likelihood of the need to make changes at later stages of the project.

The BIM model enables simultaneous participation of architects, engineers, technologists and other specialists in the project development process. This eliminates data duplication, speeds up approval processes and minimizes the number of collisions. The use of automatic model checking tools (for example, clash detection) allows identifying conflicts between engineering systems and building structures even before the start of construction work, which significantly reduces the cost of alterations.

During construction work, BIM acts as a tool for managing the schedule, resources and supplies (4D and 5D modeling). The model provides accurate

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information on the sequence of work, the need for materials and labor costs, which helps to meet the project deadlines and the planned budget [4]. Integration of BIM with monitoring systems used at the construction site allows tracking the actual performance of work and promptly making management decisions.

After completion of construction, the BIM model is used as a digital passport of the building (7D), containing information on all elements and engineering systems. This allows for effective management of the facility, planning maintenance, promptly responding to emerging faults and carrying out modernization. In the long term, the use of BIM helps to reduce operating costs and increase the service life of the facility [5].

It should be noted that the role of BIM in the management of construction projects is to ensure improved quality of design solutions, reduced project implementation times, reduced financial and production risks, as well as transparency and controllability at all stages of the life cycle of a construction facility.

The implementation of building information modeling (BIM) technology provides a wide range of strategic and operational benefits for all participants in the construction process, from the investor to the operating organization. In the context of increasing requirements for the quality, timing and transparency of construction projects, the use of BIM is becoming a tool for increasing competitiveness and ensuring sustainable development of the industry.

One of the most significant advantages of BIM is the ability to early identify design conflicts (clash detection). Combining architectural, structural and engineering solutions in a single model allows you to detect conflicts between different systems (for example, intersections of air ducts and beams) at the design stage, which helps to reduce the number of costly alterations during the construction process.

The BIM model acts as a single source of reliable information for all stakeholders, including customers, designers, contractors, suppliers, supervisory and operating organizations. This reduces the risk of misunderstandings, data duplication and errors associated with the use of outdated or contradictory documentation. In addition, the use of cloud platforms (e.g. BIM 360, Navisworks, Revit Server) provides the ability to organize collaboration in real time, which is especially important for distributed project teams [6].

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BIM technologies allow the formation of 4D models (modeling of time parameters) and 5D models (modeling of costs), which ensures more accurate planning of project implementation dates and associated costs. The use of construction logistics scenarios and scheduling based on a digital model helps to reduce downtime, optimize resource use and ensure timely deliveries.

BIM promotes process standardization, the use of certified components and an increased level of quality control. With energy efficiency parameters (6D modeling), it becomes possible to analyze heat loss, insolation, ventilation flows and propose sustainable solutions even before the start of construction work.

A digital twin of a building (7D-BIM) is used to manage the maintenance, repair and modernization of a facility. Information on the characteristics of materials, equipment serial numbers, service life and scheduled maintenance is available in real time, which facilitates operation and reduces costs [7].

BIM helps to increase the transparency of all processes, from cost calculation to control of work deadlines. This is especially important in projects with public participation, where openness and control over budget execution are required. Thus, the advantages of BIM lie not only in the digitalization of processes, but also in the profound transformation of the entire construction management system, the transition from a paper and fragmented model to an integrated digital ecosystem.

Despite the obvious advantages of building information modeling technology, its widespread implementation in the construction industry faces a number of constraints. These barriers are of both technical and organizational-economic nature and can significantly slow down the process of digital transformation of the industry.

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Table 1 - Barriers to BIM implementation in the construction industry

№	Barrier group	Contents of the problem
1	**Lack of regulatory framework**	Insufficient adaptation of national building codes and standards to BIM approaches, lack of uniform regulations and requirements for modeling.
2	**Low digital maturity of companies**	Most construction companies, especially in the regions, are not ready to switch to digital technologies due to outdated processes and lack of IT infrastructure.
3	**High initial costs**	Implementation of BIM requires significant investments in software, equipment, and personnel training. Not all organizations can afford such expenses.
4	**Lack of qualified personnel**	Lack of specialists who are proficient in BIM programs and understand the philosophy of digital design. This is especially relevant in educational institutions and at the mid-level.
5 .	**Resistance to change**	Managers and designers are often not ready to switch from familiar tools (AutoCAD, Excel) to BIM, fearing loss of control, complexity of adaptation and additional risks
6	**Incompatibility of software solutions**	The BIM platforms used in a company may not be compatible with the programs of other project participants, which hinders integration and coordination.
7	**Legal uncertainty**	Insufficient legal recognition of the status of a BIM model as a legally significant document makes it difficult to use in court, during examination and transfer to the customer.
8	**The complexity of the transition period**	The need to work "two-handedly" - with traditional documentation and BIM, until the industry is fully digitalized. This increases labor costs.

An analysis of barriers to the implementation of BIM technologies shows that the transition to information modeling is difficult due to a combination of regulatory, economic, organizational and personnel factors.

Practical experience in implementing BIM in construction projects demonstrates the significant advantages of this technology. Real-life examples confirm that the

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use of BIM can improve the efficiency of design processes, reduce the time frame for implementing construction projects, reduce the likelihood of errors and ensure transparency at all stages of the facility's life cycle.

As part of the implementation of the reconstruction project for the Helsinki-Vantaa International Airport (Finland), an integrated BIM model was used, covering architectural, structural and engineering systems. Thanks to the use of 4D modeling, it was possible to synchronize construction processes with the current operating activities of the terminal without suspending its operation. This ensured budget savings of more than 10% and a reduction in the project implementation time by 8 months [8]. BIM was used in the design of the library of the University of Sheffield (UK), taking into account the parameters of insolation, natural ventilation and the possibility of using renewable energy sources. The use of 6D-BIM made it possible to integrate building management systems (BMS) at the design stage and to assess operating costs for a 30-year period [9].

One of the facilities built for the 2022 FIFA World Cup was the Al Wakrah Stadium (Qatar), which was designed entirely using BIM. Coordination of work between architects, designers and engineering companies from different countries was carried out through cloud BIM platforms. This made it possible to minimize the number of collisions and automate the process of author's supervision [10].

Successful implementation of projects using BIM demonstrates the effectiveness of this technology in various conditions, covering a wide range of facilities, from international airports to university campuses. Modern digital technologies allow not only to create accurate 3D models, but also to effectively manage the cost, timing, operation and sustainability indicators of the facility at all stages of its life cycle.

The implementation of such projects requires the use of an interdisciplinary approach, the availability of qualified specialists, compliance with regulated standards and ensuring effective interaction between all participants in the construction process.

In conclusion, it should be noted that BIM technologies are becoming an integral element of the modern construction project management system, ensuring the integration of all participants into a single information space. Despite the existing

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obstacles, the potential of BIM in the construction industry is extremely high, and its implementation is a key factor in the transition to the digital future of the industry. To ensure successful adaptation to new technologies, it is necessary to develop educational infrastructure, improve the regulatory framework and provide state support for digital initiatives.

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