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BUILDING INFORMATION MODELLING: RULES FOR THE FORMATION OF AN INFORMATION MODEL OF FACILITIES AT DIFFERENT STAGES OF THE LIFE CYCLE

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ABSTRACT: The relevance of the stated subject of this study is determined by the importance of issues of building information models in construction work, the use of methods of information modelling at almost all stages of the operation of construction projects, and modern trends in the dissemination of methods of information modelling in construction. The main purpose of this study is to investigate the principles of building information models in construction, considering the characteristics of their application at all stages of construction projects and at all stages of their life cycle, to define the prospects for the development of these technologies in the construction industry at large. The findings of this investigation indicate the wide possibilities of the practical application of information modelling technologies when used during all stages of the life cycle of construction projects, and the imperative to comply with all requirements for models created during the preparation and planning of construction operations. The results obtained in the present study and the conclusions drawn from them are of considerable practical importance for construction workers, whose professional duties include the development and practical implementation of information models for construction projects at any stage of the construction work.

Keywords: Construction technologies, Innovations in construction, Construction object, Development of the construction industry, BIM-project.

1. INTRODUCTION

To date, building information modelling (BIM) is actively used to solve a number of technical and managerial tasks that arise at various stages of the life cycle of a construction project (Table 1). BIM is a key innovative trend in the construction sector, which has a tangible impact on all its segments.

%	Users' Experience
83	A positive return on investment
93	Belief in potential of gaining more value in the long-term future

Table 1. Statistics on advantages of BIM usage

The technology of information modelling of construction projects is based on the development and use of a virtual model of a capital construction object, which has the form of a three-dimensional information model and a certain set of related documentation [1]. The virtual model contains detailed information about the building, such as geometric parameters, construction details, material information, and connections between different building elements. This information can be used to plan and analyze various aspects of a construction project at an early stage.

For example, a virtual model can help estimate the cost of construction and the cost of operating the building; check the compatibility of building components and identify possible problems before construction begins; check whether the construction project meets the requirements of building codes and standards; analyze various project options and identify the most optimal solutions. The use of a virtual model reduces the number of errors and inconsistencies in the project, and allows for more accurate forecasts of the cost and timing.

The study is important because this kind of model is formed at the initial stages of a construction project, developed as the project progresses, and supplemented by the relevant information which is applied in practice by the other project participants, depending on their set of functions and tasks to be performed.

The information model of a construction project makes it possible to plan and analyze its characteristics at an early stage when there is a real opportunity to make changes and optimize various parameters without affecting the project budget. Designing and erecting a building or structure in a simulation helps to identify a large number of errors and inaccuracies (Fig. 1) [2; 3]. It helps to determine the best option for various construction operations

and contributes to improving the quality and speed of technical and organizational decision-making.

The introduction of BIM in construction reduces:
10% costs in general
40% the probability of errors in budgeting
10% construction time

Fig. 1. Benefits of BIM technology in the construction industry

As for the challenges of implementing information modeling, there is a need to invest in technical infrastructure and employee training. This requires high costs for software and hardware, and also requires training, which can be time-consuming and expensive. In addition, integrating information modeling can create new data security risks. Today, information technology is being actively introduced in the construction sector. A consistent transition to information technology involves the use of digital information models by all project participants at all stages of the life cycle of a construction project (Fig. 2) [4; 5].

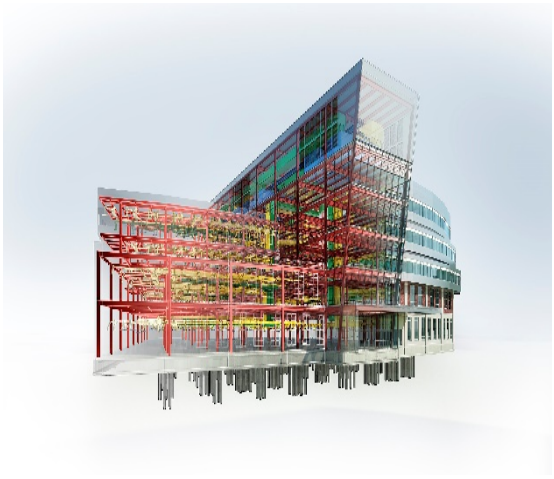

Fig. 2. An example of a 3D model for a construction project

Creating a digital information model is a laborious process that almost always proceeds with errors. A key issue in the use of information modelling technology in construction projects is the almost complete lack of generally accepted modelling standards [6; 7]. Today, any construction company moving to this technology faces many typical difficulties: confusion about families, differences in how specialists approach the task, using different family parameters for the same properties, difficulties with organizing a collaborative scheme, and so on.

Urban development is a complex process involving the consideration of large amounts of information collected and studied at the design and approval stage of capital construction [8]. The construction of a building requires permission to dispose of the land for construction and verification of the intended use, the category of construction work and the design that will meet all the stated conditions. This is a complex, step-by-step process that can be effectively implemented through the introduction of BIM technology. The main objective of this study is to investigate the principles of building information models in construction regarding the specifics of their application at all stages of construction projects and at all stages of their life cycle.

Thus, the importance of building information models in construction works was investigated, since it requires a number of information modeling methods. And for an effective analysis, it is necessary to study the current trends in the spread of information modeling methods in construction.

2. RESEARCH SIGNIFICANCE

The novelty of this investigation lies in establishing the relationship between the ways in which specific information models are used at certain stages of the life cycle of a structure, and in defining the information requirements for the models created, which are of key importance in the context of the practical implementation of these models at different stages of the life cycle of facilities. The research significance of this study lies in its potential to contribute to the advancement of Building Information Modeling (BIM) technology in the field of construction.

3. MATERIALS AND METHODS

An analytical study of the features of the building information model at all stages of its life cycle involves determining the sequence of alternation of these stages. The schematic diagram presents all these stages, illustrating the order in which they alternate over time. Meanwhile, at this stage of the study, the main groups of information models that are created at different stages of the life cycle of construction projects are identified. The key rules for creating each type of information model are listed in sequence and the need to comply with these requirements in the context of ensuring the reliability of their operation is emphasized.

Table 2 Ways of applying information models at different stages of the life cycle of construction projects

Stages in the life cycle of a construction object	Ways of using information models
Preliminary project preparation	Creating a model of a real situation →Analysis of the area allocated for construction work →Formation of models of architecture and urban planning → Determination of economic and technical indicators of planned solutions → Creating a visual model → Development of a general construction concept
Construction project designing	Simulation of the real situation in construction →Evaluation and verification of technical solutions → Interdisciplinary coordination in space and collision detection → Planning the project scope and creating a project budget → Performing engineering and technical calculations → Creating a visual model
Construction	Simulation of construction works and creation of a visual model of construction → Carrying out geodetic surveys → Quality control of construction operations → Creation of project documentation → Digital construction production
Exploitation	Planning a set of facilities maintenance measures → Tracking key performance characteristics → Modelling of remedial measures at sites → Carrying out routine repairs → Modelling of emergency situations at construction sites → Planning of a set of maintenance measures

Particular attention is paid to software for information modelling technology and the requirements for it at all stages of the construction project information model. To ensure a high degree of reliability and accuracy of the results obtained in the study of the principles of information modelling technology and key rules for the formation of information models at different stages of the life cycle of construction projects, an analytical comparison of the findings with the results and conclusions of other researchers on the stated topic was carried out. The conclusions formulated on their basis can be used as a reliable methodological basis for further studies on problematic aspects of information modelling in construction.

4. RESULTS

Building information modelling is about creating and managing information about the facility and generating decisions that determine the development of its life cycle. The BIM project is intended to enable its qualitative implementation through the use of information modelling technologies. BIM is a project task, it is a method and corresponding process of creating and practically applying information models at different stages for the successful realization of one or more project tasks. Table 2 shows the specific ways in which information models can be applied at different stages.

The main task of implementing a BIM project is to plan and organize the joint work of all participants in a construction project at all stages of its implementation. The rules for the formation of a high-quality information model of construction projects at all stages of their life cycle imply the mandatory formation of information, and technical requirements of the customer at the stage of approval of the construction plan. Such requirements are included in a special section of the technical specification for construction. These information requirements include the following mandatory provisions:

1. The goals and key objectives of a BIM project and the practical applications of information modelling technology.
2. Stages of implemented operations and information issuance.
3. Requirements for the information modelling materials used.
4. The sequence and volumes of information modelling.
5. Requirements for the composition of the information model and the levels of elaboration of its individual elements.
6. Requirements for the coding system of the structural elements of the model (if any).
7. Principles for naming project files.
8. The sequence of design and delivery of project results.
9. The quality control procedure for output information models.
10. Requirements for the approval procedure of information project files and the sequence of necessary changes to the structure of the project.

Compliance with the requirements placed on information modelling software plays a key role in terms of the effectiveness of a construction project realization. At all stages of the construction lifecycle, software solutions for information modelling fall into two groups: basic platforms; applied tools. The basic platforms are needed to support the process of creating the information model with the final technological documentation. Application tools ensure the development of the information modelling process and the realization of specific tasks. Fig. 3 shows a schematic representation of the sequential alternation of the stages of the life cycle of construction projects [9].

The approach to the consistent implementation of all stages of the life cycle of construction projects through open data exchange standards is called open BIM. Information models created at various stages of the life cycle of construction projects are divided into three main groups, shown in Fig. 4.

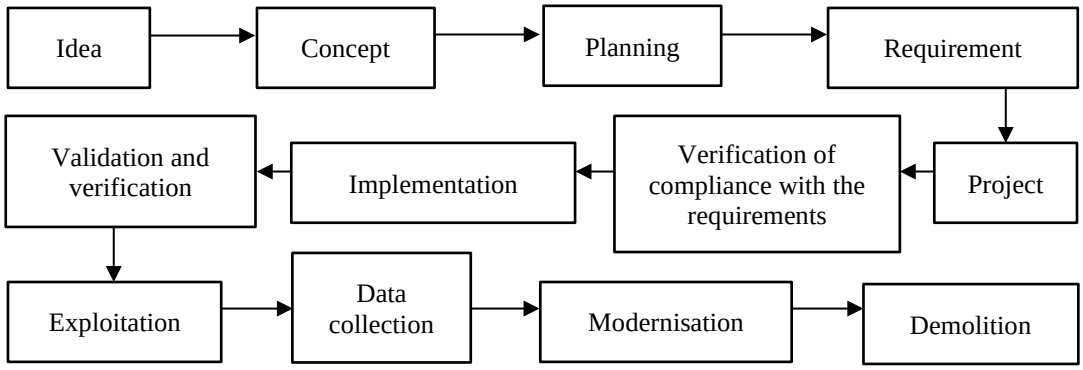

Fig. 3. Life cycle stages of construction projects

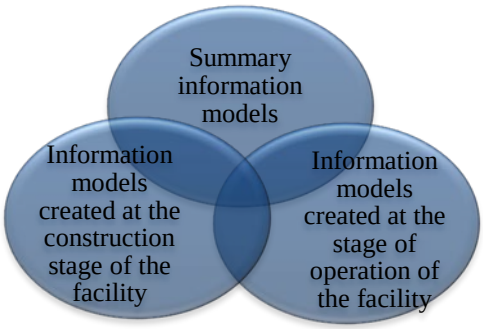

Fig. 4. Information models created at various stages of the life cycle of construction projects

The requirements for models of these types are determined by the specific features of the life cycle of the object on which such models have been created. The summary building information model is created using special software and has certain rules (Fig. 5).

Information models during the construction phase are defined and agreed upon by all parties involved in the construction process and then specified in the "Information Requirements of the Contracting Authority." Rules for creating an information model at the construction stage:

1. A construction simulation model, including an information model of the building under construction and a construction site model, is mandatory.
2. The incorporation of key building elements into the model is mandatory.
3. The terrain must be included in the planning of the construction site.
4. External and internal communications and enclosures, together with external and internal utility networks, are to be considered.
5. It is mandatory to optimize the logistics schedule and sequence of construction work on site.

Information models at the operational phase of constructed facilities require that all parties involved in the construction process agree on the specifics of their application and have certain rules (Fig. 6). When a structure is demolished, the information model can be used to extract the necessary material data for recycling purposes [10].

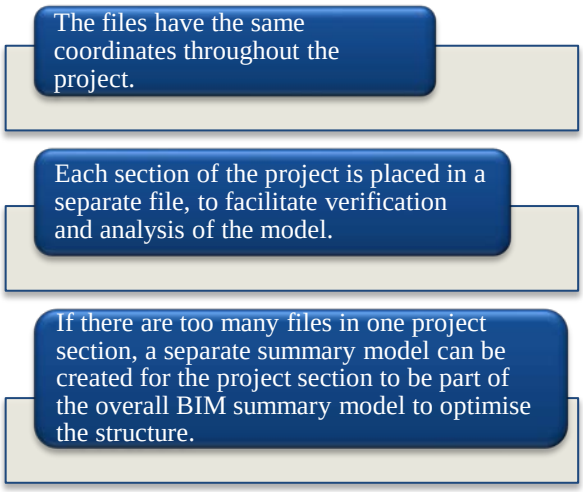

Fig. 5. Rules for creating a consolidated information model

Fig. 6. Rules for creating an information model at the operational stage

Information modelling technology in construction is effective when it is necessary to resolve issues of shaping and using the representation and space of a construction project. This is facilitated by the excellent visualization possibilities and quality conflict resolution of the mutual positioning of the construction sites. The ultimate precision of construction work is facilitated by the formation of special calculation models for certain types of simulations and calculations. The use of this kind of technology helps to find additional opportunities to improve the quality of construction work and to create optimal conditions for the development of the overall construction industry.

5. DISCUSSION

According to E. D. Revenkov, BIM technology involves information modelling of a structure [11]. The practical application of this technology means creating accurate information models of buildings or structures using a digital format. The use of such models allows for more thorough control of the entire construction of a building and the analysis of the correct sequence of construction work. The BIM significantly simplifies monitoring the condition of a building structure and reconciling the nuances of its current state with established requirements in real time. The researcher's findings are consistent with those of this study, although it is debatable whether it is easier to monitor the condition of a building structure through the use of BIM models.

A. V. Ginzburg, E. N. Kulikova, A. S. Pavlov and M. S. Vainshtein conclude that the concept of information modelling is now firmly established as a key technology for structural design [9]. The advantages of BIM modelling technology and the tasks solved through its application at the design stage are beyond doubt. In this case, the building information model is mainly positioned directly as a source of information about the project during all phases of its life cycle and is not limited to purely design. To increase the overall efficiency, individual sections of the model can be completed by different specialists using different software.

A. Lester notes that the active incorporation of information modelling technologies into construction processes has provided a real opportunity to improve their overall efficiency [12]. It is appropriate to mention the formation of a system of organizational interaction between all participants in the information modelling process, and this applies both to specific stages of the model life cycle and to the time-space between them. This necessitates objective quality control of the work done to create information models of construction projects at all stages of their construction and maintenance, which broadly echoes the conclusions drawn in the study by A.V. Ginzburg [9]. The author's conclusions correlate with the results obtained in this study to the point that implementing BIM technology in the construction sector is a very important and topical issue for modern construction organisations as it opens up significant prospects in terms of saving resources, financial and time, necessary for the quality implementation of construction projects.

O. I. Glushkova in her study on the challenges of creating three-dimensional models of construction projects mentions the fact that nowadays, it is safe to say that information modelling technologies have significantly influenced the construction sphere, as specific regulatory documents have already been adopted, which regulate the requirements for information models of large-scale construction projects and the sequence of their development at different stages of the life cycle [13]. The researcher concludes that these instruments improve the substantiation and quality of design decisions, increasing the level of safety in construction and operation, along with basic requirements for the creation and operation of information systems that interact with each other throughout the life cycle of a structure and implement the technology of BIM, and establishes requirements for the components of their information models. The findings suggest a promising avenue for exploring the future use of building information models in construction safety assessment, which has not been directly addressed in this scientific study and significantly supplements its insights.

M. Note, while exploring the software issues of modern BIM technology, points to the fact that in today's environment, construction work is managed through the use of a multitude of programmes that provide quality management of the available information resources [14]. The author also concludes that BIM technology, which was first introduced in the 1970s, has long been firmly established in the range of construction modelling techniques. Visual planning technology is just taking its first steps in this market. Models generated by BIM allow the entire sequence of design and construction work to be traced over time, which is consistent with the results obtained in this study. The author notes that today this technology is already actively used in many construction projects at all stages, starting from design all the way to demolition, and is used by both project designers and builders.

According to another researcher S. Montgomery, who studied the object-oriented engineering of construction works, BIM makes it possible to display a building in a 3-D model with all its components, such as foundations, roofs, walls, electrical and water supply systems, floors, etc., as

early as during the design phase, with each component having all the technological information directly related to that component [15]. This offers an additional benefit by providing the information necessary to draw up a reliable project budget and by demonstrating the sequence of construction activities on a time-bound basis. In addition, information modelling technology can be successfully applied both to the economics of a building project and to the creation of effective presentations highlighting its main design and construction features and strengths. These findings are somewhat inconsistent with the results of this study since the creation of quality presentations requires the use of information sets that do not require the use of BIM technology.

A study by M. Casini on the various aspects of construction work highlights the fact that effective automation of the construction industry enterprise is often difficult to achieve from the standpoint of the introduction of BIM [16]. Such a process requires a preliminary structural-functional analysis of the whole range of construction operations performed by the company in question, along with the design and technical documentation and the qualifications of its employees and their responsibilities. It is also essential to make an in-depth analysis of the tasks to be carried out by implementing a building information modelling system. The scientist stresses that it is the information support that largely determines the standards of the technological operations performed, but also underlines the question of whether old standards should be maintained, or new ones adopted, thereby complementing the results of this scientific study.

The problematic aspects of the practical application of BIM technology are covered in a study by K. Storm [17]. The author concludes that the use of BIM technology is fully justified by the need for high-quality visualization tools and the possibility of displaying the relative positioning of several objects. Other areas of the process, however, give priority to the need for computational models and calculations which include solutions for the creation of new shapes and the use of spatial reference points and times of representation of a particular object. Often, it is not possible to obtain these models from the BIM database, which precludes the use of this data in the integrated modelling process and the subsequent operation of an already erected structure. The researcher's findings seem to be debatable, as obtaining the necessary data from the information model requires the use of a pre-prepared database, which is not directly related to the problems of integrated modelling.

The quality use of construction databases is the subject of a joint study by R. K. Dhir, J. de Brito, R. Silva and C. Q. Lye [18]. In examining the various subjects of the selection of building materials, the authors point to the fact that the construction industry is gradually moving to the latest information technology, which implies a completely different approach to building design, construction, organization of document management and various simplifications of the model created. BIM is the foundation of this approach, which involves the practical use of large amounts of information on facilities built and under construction, but also on buildings that have already been in use for some time and those already demolished. The aim is to coordinate input information and organize data exchange, storage, and processing. The extensive potential of modern software, on which this technology is based, provides a high-quality solution to all tasks. The conclusions of the authors' group generally coincide with the results obtained in this study, further defining the purpose of using BIM for modern construction projects.

H.-W. Wang, J.-R. Lin and J.-P. Zhang addressed the role of software in building information modelling in a joint study [19]. The authors have concluded that, in fact, building information modelling is software that makes it possible to create 3D models of buildings. It can be used to calculate the materials to be used in the construction phase and to estimate the time required for all construction activities. It also allows for forming a model of a building, both exterior and interior. The advanced technology makes it possible to consider and calculate all the features of future construction operations as early as the design stage. The authors' findings are complementary to those of R.K. Dhir, J. de Brito, R. Silva and C. Q. Lye [18] and are fully consistent with the results of this study. This opinion is also shared by R. Mora, L. J. Sanches-Aparicio, M. A. Mate-Gonzales, J. Garsia-Alvares, M. Sanches-Aparicio and D. Gonzales-Aguilera [20]. As a result of their joint study authors have concluded that DIM opens up new opportunities for the development of the construction industry, as it allows the storage and processing of information relating to the various stages of construction work to be taken to a whole new level. Information can be collected either directly during construction operations or prepared in advance during the design phase of the construction project. At the same time, the authors highlight the importance of developing design documentation covering all the nuances of managing the technology and storing the construction project databases.

The creation of a regulatory framework for the practical application of information technology in construction was addressed in a joint study by Z. Ding, S. Liu, L. Liao, and L. Zhang [21]. According to the authors, in some countries, the use of building

information technology is mandatory for both private and state projects related to tendering. Scientists note the fact that additional software, in particular plug-ins and scripts, has made the application of this technology even more attractive by reducing the overall cost of the work. The outcome is a decrease in the overall cost of construction projects that are carried out by applying building information modelling technology. The findings of the researchers considerably expand the results of this study, presenting an entirely new perspective.

The construction industry can adapt to changing trends in information modeling technologies using different strategies and approaches. Among the most relevant are: investments in technology, staff training, cooperation with leading software vendors, changing the business model, and cooperation with specialists. Adapting to BIM technologies can provide a significant level of competitiveness in the construction industry and help increase productivity [22, 23]. In addition, it can help ensure high-quality construction work, reduce construction costs, and improve the quality of projects. The use of information modeling technologies can also increase the level of cooperation between different participants in the construction process, reduce errors, and ensure more accurate and faster data processing [24]. Thus, policymakers and stakeholders can support the development of building information modeling technologies by taking the following actions:

1. Providing investment - governments and other stakeholders can provide funding for research and development of new BIM technologies, as well as to support the adoption of these technologies in the construction industry.
2. Regulation - governments can ensure that regulations and policies are in place that define standards and requirements for the use of BIM in construction and facilitate their implementation.
3. Partnerships - governments can facilitate partnerships between different stakeholders, including construction companies and BIM software vendors.
4. Supporting education and training - governments can support the development of curricula and provide funding for BIM training.

6. CONCLUSIONS

Building information modelling involves the creation of information models of construction projects as digital representations of their physical and functional characteristics. To this end, a body of features and data is used to act as a collective knowledge resource about a construction project throughout its lifecycle. The regulations on the formation of information models at all stages of the lifecycle of construction projects describe the set of operations required for the qualitative functioning of these models. This mainly concerns three key groups of models: summary information models, BIMs formed during the construction phase, and those formed during their operation phase. These rules describe the key factors for modelling and data collection required for a complex realisation of a construction project. Strict compliance with these regulations guarantees the high quality of models, which is of fundamental importance regarding the future introduction of information modelling technology in the construction sector.

The efficient application of BIMs in the construction industry provides a high level of control over the nature and efficiency of operations at all stages of the life cycle of a construction project, from its planning through to the demolition of the facility. The main objective of building information modelling is to ensure that the decisions made during all phases of the life cycle of a building or facility are efficient, reasonable, safe, and effective. This leads to significant prospects for expanding the scope of the practical application of building information modelling. Future applications of BIM technologies may include virtual reality, artificial intelligence, the Internet of Things, accounting systems, drones, and data analytics. The widespread use of BIM technologies can have significant benefits for the construction industry, including reducing construction time and costs, increasing planning efficiency and accuracy, reducing risks and increasing safety on construction sites, improving the quality of construction projects, and ensuring the ease of managing buildings after they are commissioned.

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