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APPLICATION OF THE BUILDING INFORMATION MODELLING (BIM) FOR BRIDGE STRUCTURES

Viktor Moshynskyi, Roman Trach✉, Pavlo Striletskyi

National University of Water Management and Nature Resources, Rivne, Ukraine

ABSTRACT

After the concept of knowledge management had been firstly applied in construction projects, scholars began to discuss how to manage knowledge in specific projects, taking into account problems associated with the specifics of the construction industry. An important component of a modern knowledge management system are systems which pay special attention to information technology (IT). The IT system is designed to search, collect, store, classify, transfer and reuse information and knowledge and enables collaboration, knowledge sharing and best practices. An example of the use of an IT system in construction is the introduction of computer methods of information modelling (BIM) into practice at all stages of a construction cycle. This article investigates basics of the concept of information modelling in construction and analyses the practical application of this concept in the bridge construction. The advantages arising from the use of BIM at different stages of the life cycle of the bridge object have been systematized.

Key words: information modelling, BIM, construction project, bridge, life cycle

INTRODUCTION

Building information modelling in the construction industry is a process involving the generation, processing and management of digital representations of physical and functional characteristics of buildings and places. Building information models are files containing proprietary construction, technological, economic and other data, which can be extracted, exchanged or networked to support decision-making regarding a building or other built asset.

Modern construction projects contain numerous participants. One of the most important elements affecting an implementation of construction projects is the effectiveness of cooperation between project members (Trach & Lendo-Siwicka, 2021). Poor cooperation leads to a separation of the construction process into stages, a great number of changes and rework, and as a result the duration of the project and an increase of rework costs (Trach, Lendo-Siwicka, Pawluk & Polonski, 2021). The development of innovations of the building information modelling (BIM) concept was a response to the above-mentioned problems. Building information modelling is one of the most promising conceptions in architecture and engineering and construction (AEC) industries.

The National Building Information Model Standard Project Committee defines BIM as a digital representation of physical and functional characteristics of a facility (National Institute of Building Sciences [NIBS], 2014). Building information modelling is a collective knowledge resource about a construction

Viktor Moshynskyi https://orcid.org/0000-0002-1661-6809; Roman Trach https://orcid.org/0000-0001-6654-9870; Pavlo Striletskyi https://orcid.org/0000-0001-6533-0121
✉r.v.trach@nuwm.edu.ua

object, a reliable basis for decisions during its life-cycle. One of the main ideas connected with BIM is the ability to define and describe not only geometric parameters of the construction object, but material parameters, money and time factors, ecological parameters as well. Building information modelling enables to describe an object covering all phases related to its emergence and functioning from initial conceptual works through the stages of design, implementation, operation, and up to liquidation.

Building information modelling concept is an alternative to the existing traditional CAD (Liao & Teo, 2019). The new system offers significant intellectual benefits and ability to interact with all members of the construction process (Sacks & Eastman, 2006). With BIM technology, an accurate virtual model of a building is constructed digitally. Such computer model contains exact spatial geometry of the structure and necessary data for a proper organization and execution of construction works and project management (Eastman, Teicholz, Sacks & Liston, 2011).

LITERATURE REVIEW

The implementation of BIM in AEC projects in the last 10 years showed that the digitalization in construction environment has a significant impact on optimization of all the services and communication between all participants of an investment (Azhar, Khalfan & Maqsood, 2015). The application of BIM in Western European countries has been increasing and provides real savings of 20% in design and construction stages of AEC projects (Siniak, Źróbek, Nikolaiev & Shavrov, 2019).

Since 2018, the level of interest in BIM in Ukraine has grown significantly, however the overall rate of implementation throughout the country remains quite low. Ukraine, like many Western countries, needs to develop a plan and ensure uniform conditions for its implementation into real AEC project, especially that since 2019 by decision of the Ukrainian Ministry of Regional Development and Construction the use of BIM will be mandatory (Ministerstvo rozvytku hromad ta terytoriy Ukrayiny, 2018). Actually, there are some examples of the use of BIM on Ukrainian construction market: design and construction of a blast furnace at the Zaporizhstal metallurgical plant, airports in Zaporozhye, Ivano-Frankivsk and Vinnitsa, concrete production plants DBK-Industry and 3 Concrete (Lebedev, 2018).

In accordance with Romanenko and Chaplai (2017), the following actions should be taken: digitalization of the construction market, introduction of a clear classification of all information on the environment of the construction industry and automated exchange of information and databases in an open format in line with international standards, access to information and public education in the field of BIM (school, universities, construction companies), cooperation of all public organizations, associations and business partners. The main issue which needs to be addressed consists in conversion of the construction industry to the principles of life cycle management and market pricing (Kuybida et al., 2018). In recent years, the value of the Ukrainian construction market has amounted to 100 billion hryvnias, but the losses of enterprises amounted to 5 billion hryvnias, which is related to the lack of clear pricing rules. Thus, according to experts, the implementation of BIM technology in Ukraine can lead to an economic advantage at the level of 20–50% at the design stage, and up to 40% at the construction stage due to the labor and cost transparency, the factory production of building components, the removal of potential errors, repairs and rework, and a clear time schedule for construction investment (Siniak et al., 2019).

According to Mårtensson (2000), a hierarchical structure of data, information and knowledge exists. Usually, the knowledge is at the highest level of this hierarchy and data is at the lowest level. Typically, data is described as a set of discrete, objective facts concerning the events. Information, however, is a set of data and related explanations, interpretations and other textual material related to a particular object, event or process. The knowledge is a more complex concept to define.

Building and construction services can be very knowledge-intensive, and both a specialized expertise and know-how are real products of knowledge-intensive services. A significant part in the cost of developing a modern construction project consists of knowledge-related elements (design, evaluation of alternative cost options for various building components, advice on contractual aspects, risks assessment, project implementation methods, quality and safety issues).

After the knowledge management concept had been firstly applied in construction projects, scientists began discussing how to manage the knowledge within specific projects, taking into account problems associated with the building and construction industry specifics. One of the specific problems, characteristic to the project management, is a loss of some previously acquired knowledge after completion of the project implementation. At the same time, several knowledge management problems arise: the knowledge is not used where it is generated; the projects completed, respective knowledge is lost; and moreover, it is lost in the event of the departure of contractors, peripheral workers, or at changes in the project team (Chan et al., 2006).

An important and integral component of modern knowledge management system is brought by the information systems which pay special attention to information technology (IT). This system is designed to search, collect, store, classify, transfer and reuse information and knowledge and ensures an efficient collaboration and exchange of the knowledge and best practices (Earl, 2001; O'Leary, 2001).

RESULTS

An example of application of an information system in the building industry is a practical implementation of information modelling computer methods at all stages of a construction cycle. Building information modelling technology is based on the parametric modelling concept, oriented on a building object. This parametric modelling is one of the fundamental features which distinguish BIM programs from all other CAD design systems. Initially, this approach was widely used in mechanical engineering, and for the last decade it has been particularly actively implemented in the architectural and construction design.

Building information modelling includes diverse information and knowledge about the construction site and facility built: geometry, spatial relationships, geographical data, quantity and properties of building materials and components, their specifications, fire resistance, project cost, analysis of outdoor lighting. In case of design changes, BIM tools can integrate and organize changes in the entire project (Autodesk, 2002). Moreover, BIM can be used to the object management integration. The main principle of BIM is cooperation of various stakeholders during individual phases of the object's life cycle, allowing implementation, receipt and update of information in order to support and reflect each user's role. Building information modelling models are basically large structured data convenient for all users involved. Meanwhile, the data in BIM are gradually becoming semi-structured when combined with other information systems or sensor technologies such as: geoinformation systems (GIS), global positioning systems (GPS), augmented reality (AR), laser scanning and automatic object identification (RFID). Data sources in a construction project are massive and complex, but when correctly operated they allow generating a huge amount of information and knowledge (Trach, Pawluk & Lendo-Siwicka, 2020). These big data together with BIM can be used to represent information about the construction object, namely: the object structure, construction works schedule, materials and equipment use, construction cost, labor relations, energy consumption and use during the entire construction project life cycle. The big data and BIM combine all-in-one the fragmented information about a construction site throughout its entire lifecycle.

Building information modelling serves as a platform for data collecting and sharing at all stages of the object's life cycle. Shared access to the same information by all project participants allows using this information for various calculations, obtaining additional information and knowledge.

In addition, the shared access allows for more consistent decisions in different areas of construction and at different stages of the project.

Information modelling in building and construction field has also found its practical application in the construction of bridges and tunnels. An example here is the Hong Kong-Zhuhai-Macau bridge project, which provided for the creation of artificial islands, bridges, and tunnels (Fig. 1).

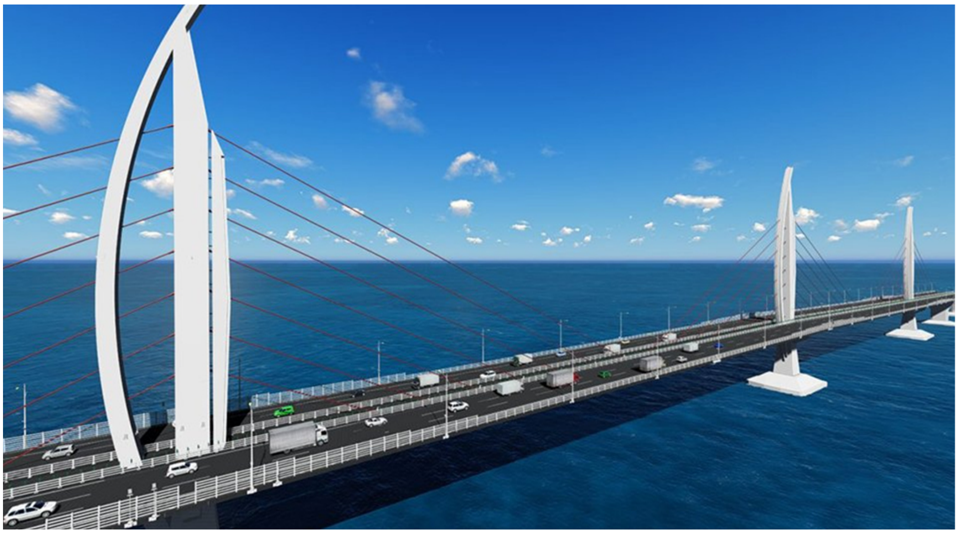

Fig. 1. 3D-model of a part of the Hong Kong-Zhuhai-Macau bridge (https://damassets.autodesk.net/content/dam/autodesk/draftr/4358/cropped-1534866310.jpg)

The tunnel section is about 6.7 km long and the bridge section is 22.9 km long. In addition, two artificial islands were built. This large-scale project was completed in December 2017.

The main purpose of using BIM in the project was:

- to optimize the process of creating high-quality drawings and reduce the number of inconsistencies and changes in the project;
- to create a visualized 3D project model by submitting a project profile and additional plans;
- to implement a 4D-work progress management enabling to optimize construction processes and to ensure the construction work actual performance by inspecting the site in a form of a 4D BIM model;
- to provide a 3D control of traffic modelling devices and 3D monitoring using BIM data which accelerated the consideration of requests for information, device placement, cables and requests for laying the equipment management routes.

BUILDING INFORMATION MODELLING ADVANTAGES

Building information modelling technology is applied throughout the entire project life cycle, including design and construction as well as operation and maintenance of systems (Fig. 2).

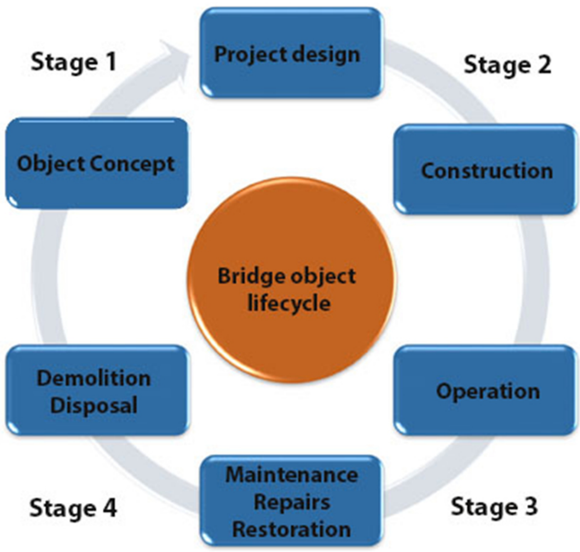

Fig. 2. Life cycle of a bridge object (Salamak, 2020)

Consider the totality of advantages arising from BIM at different stages of the bridge construction project implementation.

Using BIM at the concept stage allows to:

- evaluate design features of a future building;
- choose building materials;
- choose the location of an object, taking into account climatic and geological features, road traffic and business activity;

- predict costs and expected profit from the project implementation;
- take into account the environmental situation;
- predict the project's image.

Using BIM at the design stage allows to:

- form expert systems for the analysis of design solutions;
- develop the concept of variant design based on BIM models using the intelligent analysis of a project documentation;
- apply a deep analysis system to find "hidden knowledge" for synthesizing and evaluating the effectiveness of design solutions in the project design process;
- detect BIM models' collisions with more accuracy;
- prepare the highest quality tender documentation;
- use more accurate source data;
- visualize and build models of design solutions;
- improve cross-industry cooperation;
- analyze the project risks.

As a result of modelling various design options at a detailed level, it was possible to improve the project team internal cooperation. For example, the drainage pumping station pipeline, according to the general layout, took up most of the space and left little space for evacuation. Thanks to the use of BIM, the spatial relationship between architectural projects, structures, and engineering systems can be visualized and discussed.

Using BIM during the construction phase allows to:

- reduce construction costs;
- improve work quality and safety;
- improve a construction management and work control;
- render a work planning more efficient;
- monitor the work progress;
- reduce the risk level.

Using BIM at the operational stage allows to:

- get access to information obtained in previous stages;
- elaborate convenient schedules of repairs and maintenance;
- provide for the warranty management;
- provide for the asset management support;
- render better service planning;
- save costs over the life cycle;
- improve the survey and assessment of technical condition;
- use expert tools.

An example is the joint use of BIM and Internet of Things (IoT) systems during the operation stage of a bridge (Fig. 3; Zhao et al., 2019).

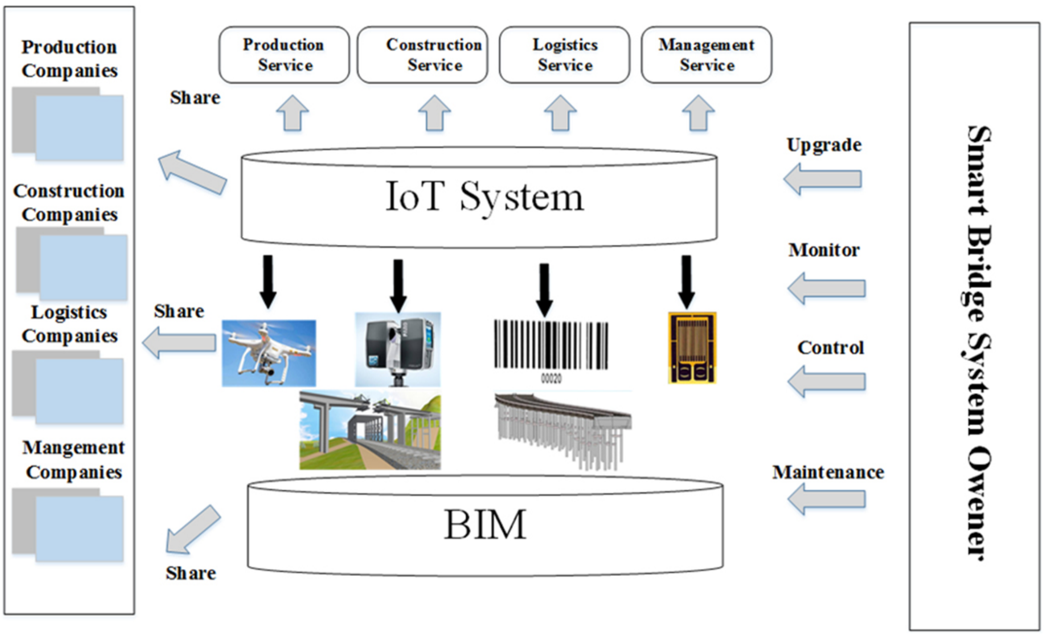

Fig. 3. Using of BIM and IoT system during the bridge operation stage (Zhao et al., 2019)

Various sensors (with help of transducers) can detect technical defects and warn about emergencies occurring in communication systems, measure pressure, temperature, environmental parameters, load intensity, human flow activity, and much more parameters. Technologies of data collection and analysis cover various workflows, making data available for analysis and allowing generation of up-to-date solutions. Over the past decades, research has been conducted to develop methods for detecting and diagnosing malfunctions and to apply efficiently the existing knowledge about the building to improve its maintenance during the facility operation stage. A variety of sensors and the IoT allow for constant interaction between a physical structure and its digital model. Sensors are used to properly monitor the object and its technical condition in real time.

Summing up, it should be noted that the use of information modelling in the construction of bridges and tunnels creates a number of advantages for key project participants at all stages of its implementation and exposes promising prospects in the future.

CONCLUSIONS

The building information modelling (BIM) is a system which allows digital description of many parameters for a construction object at the design, implementation and consequent use stages. Essential is that a description of the BIM parameters gets a parametric representation which is a fundamental advantage and an innovative approach. But one of the main ideas associated with BIM functionality is the ability to define and describe not only the geometric and material parameters of an object, but also its monetary and time factors. In such a way, BIM allows the description of an object, covering all phases related to its origination, creation and operation, from the initial conceptual design, through the design implementation stages, embodiment and works completion stages, including object operation, and even liquidation. The use of BIM in bridges and tunnels construction provides the project key participants with a number of advantages at all project implementation stages and represents clearly promising prospects for the future.

Authors' contributions

Conceptualization: V.M. and R.T; methodology: R.T.; validation: V.M. and S.P.; formal analysis: V.M. and S.P.; investigation: R.T.; resources: V.M.; data curation: S.P.; writing – original draft preparation: S.P.; writing – review and editing: V.M. and S.P.; visualization: R.T.; supervision: V.M. and R.T.; project administration: R.T.

All authors have read and agreed to the published version of the manuscript.

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WYKORZYSTANIE MODELOWANIA INFORMACYJNEGO (BIM) W TRAKCIE CYKLU ŻYCIA OBIEKTÓW MOSTOWYCH

STRESZCZENIE

Po pierwszym zastosowaniu koncepcji zarządzania wiedzą w projektach budowlanych naukowcy zaczęli dyskutować, jak zarządzać wiedzą w konkretnych projektach z uwzględnieniem problemów związanych ze specyfiką branży budowlanej. Ważnym elementem nowoczesnego systemu zarządzania wiedzą są systemy, które zwracają szczególną uwagę na technologie informacyjne (IT). System informatyczny jest przeznaczony do wyszukiwania, gromadzenia, przechowywania, klasyfikowania, przesyłania i ponownego wykorzystywania informacji i wiedzy oraz umożliwia współpracę, dzielenie się wiedzą i najlepszymi praktykami. Przykładem zastosowania systemu informatycznego w budownictwie jest wprowadzenie do praktyki komputerowych metod modelowania informacji (BIM) na wszystkich etapach cyklu życia obiektu budowlanego. W artykule przeanalizowano podstawy koncepcji modelowania informacji w budownictwie oraz praktyczne zastosowanie tej koncepcji przy budowie mostu. Usystematyzowano korzyści wynikające z zastosowania BIM na różnych etapach cyklu życia obiektu mostowego.

Słowa kluczowe: modelowanie informacji, BIM, projekt budowlany, most, cykl życia