Effective Building Operation Through the Building's Digital Twin; Case Study

Denis Konovalov[1)], Jozef Švajlenka[2*)], Dušan Katunský[3)]

[1)] Institute of Architectural Engineering Faculty of Civil Engineering, Technical University of Kosice, Slovakia; ORCID: https://orcid.org/0009-0008-9084-929X
[2*)] Department of Construction Technology and Management, Faculty of Civil Engineering, Technical University of Kosice, Slovakia; e-mail: jozef.svajlenka@tuke.sk; ORCID: https://orcid.org/0000-0002-9273-9755
[3)] Institute of Architectural Engineering Faculty of Civil Engineering, Technical University of Kosice, Slovakia, ORCID: https://orcid.org/0000-0002-6436-5792

http://doi.org/10.29227/IM-2024-02-16

Submission date: *03.06.2024*. | Review date: *22.06.2024*

Abstract

In recent years, many industries have moved forward significantly in terms of digitisation. However, the construction sector is lagging far behind. A suitable solution to move the construction sector forward is the use of the Building In- formation Model (BIM). A building model developed in this way can be used not only for design and construction, but in recent years it has been shown that this model has the greatest benefit in the management and maintenance of t h e building itself. Thanks to modern support tools, it is possible to prevent failures in time and thus prevent the building from being decommissioned. In this context, this paper focuses on supporting digital tools such as: the in- formation model of the building, applications for building management and maintenance, which can be linked to the information model of the building to obtain a "living" building, which can be called the digital twin of the building. This paper also includes a case study that just deals with the connection of an existing building during management and maintenance with a BIM model. The aim of this paper is not only to increase the progress of digitalization in the building sector but also to show what benefits digital tools bring with them what are the future lines of research and what are the challenges associated with this issue.

Keywords: *Buildings; BIM; CAFM; Digital twin*

1. Introduction

Building works contain more and more modern technologies, which bring more comfort to the users and also the possibility to optimize operating costs, thus becoming more and more difficult to implement. Many stakeholders such as the architect, developer, contractor, professionals and ideally the future user of the construction work [1]. It is the communication that should not start with the design itself and end with the approval, but should also follow during the use of the construction work itself. If all the changes that have occurred during the real- ization are incorporated and the digital model is taken over by the administrator and subsequently used in the administration, then it is possible to speak of a digital twin [2]. Grieves was one of the first to define a digital twin in 2012 as: , "A physical product in a real space, a virtual product in a virtual space, and a union of data and information that connects two spaces" [3]. According to Boschert and Rosen [4], a digital twin is understood as a prod- uct or system that includes almost all the information that is needed throughout the lifecycle. Author Schleich [5] describes in his paper , that one of the capabilities of a digital twin is the ability to prevent an unexpected event before it occurs. In recent years, it appears that the Building Information Model (BIM) has contributed to the construction sector moving forward a bit as well. BIM is perhaps the most widely used method nowadays in the design, implementation of building works and also in maintenance [6]. BIM does not only mean that a model is made and all clashes are visible in it but also that all information, data and data must be recorded in this model and kept for future needs whether it is a change of manager for a given building but also, for example, when a given building has reached its lifespan and has to be disposed of [7]. According to Bormann [8], the essence of BIM is based on the idea of continuous use of digital models throughout the entire life cycle from the design phase to the longest phase, which is the operational phase. Some of the studies point to the fact that the total cost in the operation phase is five to seven times higher than the initial investment cost. This fact raises the question of how to make the most efficient use of the building information model in the actual management and maintenance [9]. A case study by Lina [10] shows that the implementation of BIM during the operational phase will increase the performance of the management, however, the users have to develop appropriate plans to ensure that the building runs optimally and that the model is continuously updated and used properly.

This paper provides basic information on what is the information model of the building, how this model can be linked in the operation phase using different software solutions. The paper should also serve to assess the potential for added value and also identify potential problems.

1.1 Building information modelling and Facility management

The concept of information modelling has been known since 1974, but the name BIM - Building Information Modelling has been used since 2002. Building informa- tion modelling represents a significant shift in the construction industry. The basic pillar is the collaboration between the involved participants [11]. In 2007, a survey by the Stanford University Cen- ster for Integrated Facilities Engineering highlighted the basic benefits that BIM offers. The key benefits included a 40% elimination of off- budget costs, an 80% reduction in the time required to produce a cost estimate, and last but not least, a reduction in design time of up to 7% [12]. The information model itself can also be used in Facility Management. Facility management (FM) is a modern method that manages the support activities of the entire organisation. The word "Facility" translates as a building that houses a facility but also the services that are provided with a specific

purpose. The word "management" means management or administration. Every building object is implemented with the knowledge that its purpose is already defined and it is created for different entities or organisations [13]. With the input of the Facility Manager in the design phase, it is possible to influence up to almost 80% of the operational costs [14]-[16]. However, a study conducted in the Netherlands indicates that the implementation of BIM in the design phase with subsequent use for management and maintenance purposes is minimal [15]. One of the main factors why this is the case is the mismatch between people and processes. A given user who wants to manage a given construction work needs to know how to use the given information that is contained in the model [16].

1.2 Activities in Facility management

Facility management itself includes fairly routine activities that must be carried out in a building [17]. Facility management is mainly about managing support processes it is not about revolutions but it is mainly about making the service continuously improve The main benefits include: cost reduction, better focus on the main activity of the business and it also indicates specifically which people are providing communication and it also clearly indicates the quality of the service and the cost of running it [18]. In the figure (Fig. 1) shown below the support services can be seen. These services also include BIM, which is able to facilitate individual services by digitizing individual processes.

Fig. 1. Some of the activities included in Facility management. “Modified according to [18]“.

2. Case Study of an Administrative Complex

As a practical example of the use of building information model and CAFM software, an administrative complex located in Slovakia in the city of Košice was chosen. This building can be characterized as an office building that was commissioned in 2014. A floor plan of a typical floor is shown in the ‘Figure 2’along with the area indicators.

Built-up area of the main building:	410,60m^2
Total floor area of the main building:	10 501,70m^2
Built-up area of the main building:	38 279,00m^3

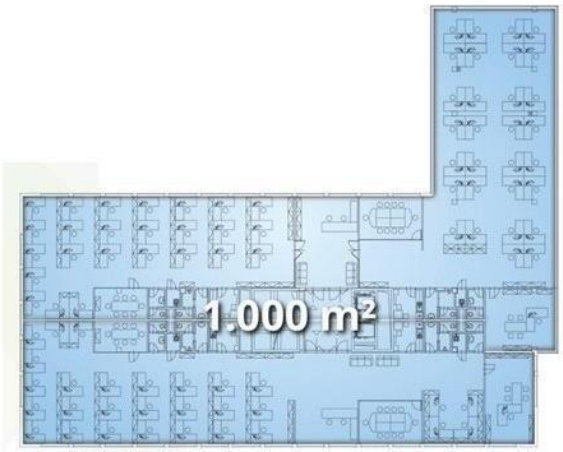

Fig. 2. Typical floor of an office building

3. Creation of a 3D model of an office building for use in the cafm system

The office building is an existing building that was built 10 years ago. Based on the provided 2D documentation, a simplified 3D BIM model of the office building was created in the Ar- chicad environment. The created 3D model can be used in the management and maintenance of buildings and thus streamline and optimize the entire operation of the building in the phase of use. ‘Figure 4’ of the created building model.

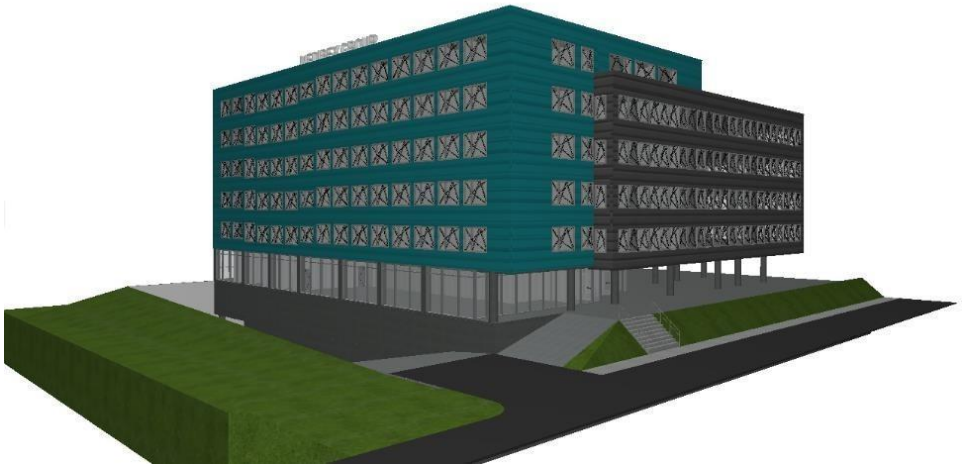

Fig. 3. Created BIM model of the office building (source: author)

One of the advantages of the created model is that if this model is exported, for example, to the native .ifc format, it can be browsed using applications that support such a format and subsequently get an overview of where its building blocks are located and get more detailed information about them. In the figure below, a 3D model of the heat pump is created.

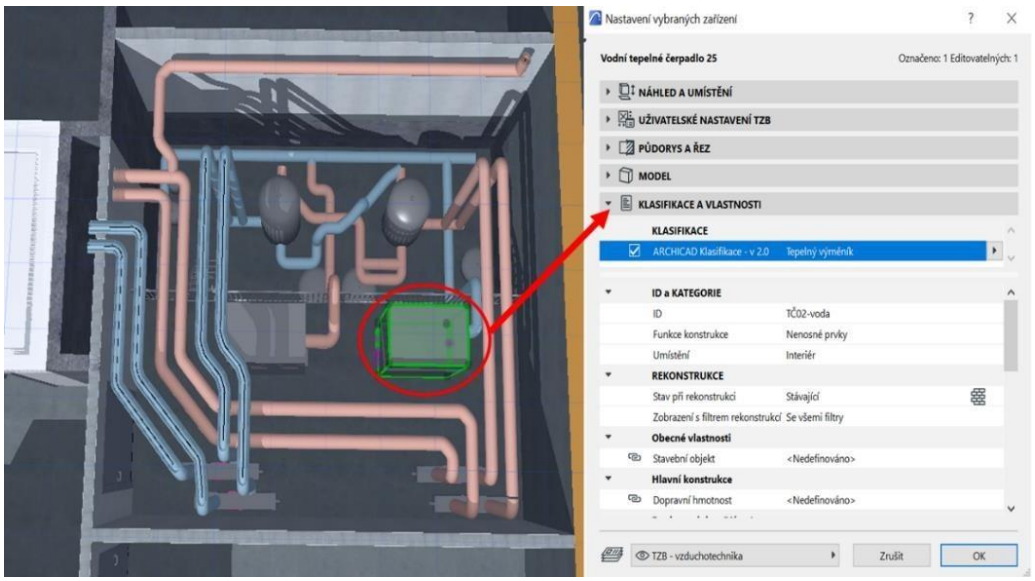

Fig. 4. More detailed information about the element in the model (source: author)

It is necessary to note that in the case of layout changes, it is necessary to observe the fire sections that were already established during the creation of the project documentation. From the model it is also possible to obtain information on the energy performance of the building or on the energy prices that can be determined for the individual areas used by the tenants. For the purpose of the work, a machine room was selected, which is located on the second underground floor, where the technological equipment necessary for the operation of the entire building is located. This room was represented in the building model. A comparison of this room with reality is shown in the following ‘Figure 5’.

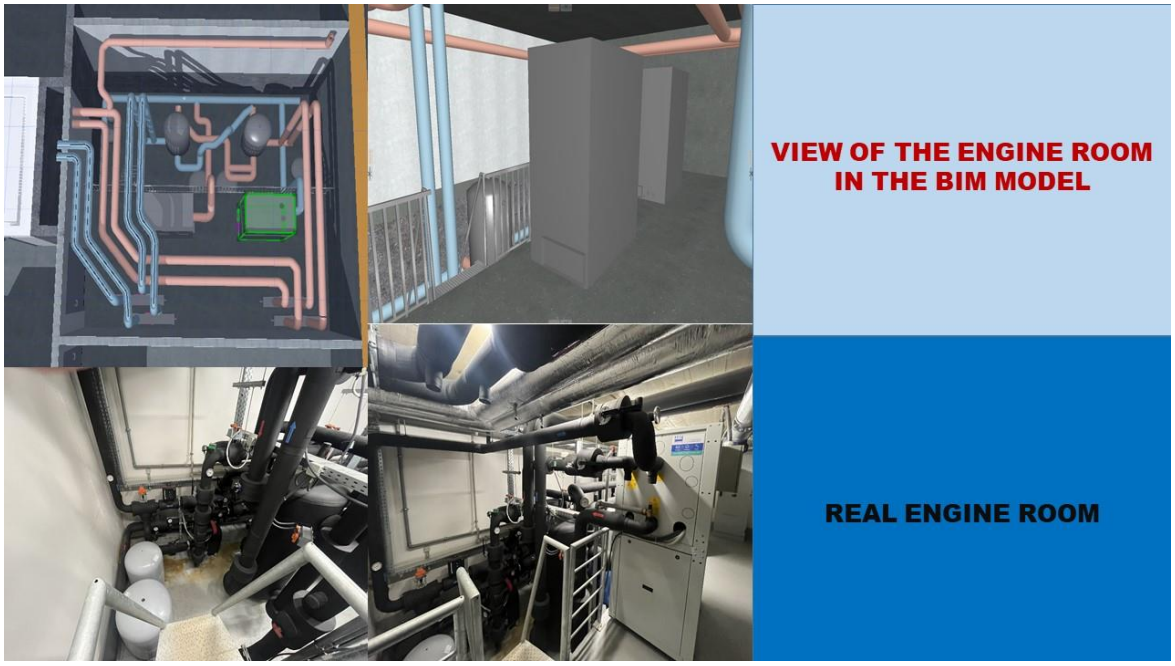

Fig. 5. Engine room 2.PP - BIM model vs. reality (source: author)

The engine room has been modelled on the basis of the project documentation, which may differ in some parts from the actual design. Primarily in the routing of the wiring.

4. Benefits of the bim model in the construction use phase

It is advisable to use the building information model already during the design phase of the project, where many collision situations can be avoided. Later on, the contractor of the building itself will appreciate such a well-processed project documentation, as many discrepancies and details will be resolved already in the design phase. For the office building in question, an information model of the building was not made in the design phase of the project. It is an undeniable advantage for the phase of use of the construction work if such a model is produced. The building owner or manager thus does not lose sight of the layout changes or the arrangement of the leased premises. It is a prerequisite to update the model according to the current state and requirements of the client w h o rents the space. For the purpose of this case study, a BIM model of an admin- istrative building in the occupancy phase was created, where the building has been in use for ten years. During this period the tenants' requirements have varied considerably. Thus, with incorrect administration, it could easily happen that the layout of the space in question did not match the design documentation or the changed layouts before the building itself was commissioned. This aspect can be eliminated by making an in- formation model of the building.

Fig. 6. Total floor area (m^2) displayed by the BIM model using Bim Point (source: author).

5. Advantages and disadvantages of using software solutions in building management and maintenance

For the management and maintenance of the office building, a model of the building was created, which was then exported to Bim Point and linked to the software solution SW Klid. These software solutions have indisputable advantages for the building owner and the building manager themselves. However, there are also disadvantages to implementing these software solutions, which are summarised below:

Tab. 1. Advantages and disadvantages of implementing software solutions in building management and maintenance (source: author).

Software solutions BIM Point and SW Klid	
ADVANTAGES	**DISADVANTAGES**
THE OWNER AND MANAGER HAS A COMPREHENSIVE OVERVIEW	PROCUREMENT OF SOFTWARE SOLUTIONS
EASIER ORIENTATION IN THE BUILDING	THE NEED TO CREATE DATA BACKUPS
WARNING IN SW DURING MAINTENANCE, FAILURES	CHANGES IN THE BUILDING MODEL ARE PERFORMED BY THE CREATOR OF THE MODEL
OPTIMIZATION OF COSTS IN THE BUILDING	WHEN YOU CHANGE THE MODEL, A NEW EXPORT IN IFC FORMAT IS REQUIRED
ELEMENT RECORD STORAGE	STAFF TRAINING IN USING NEW SW

It is clear from the comparison that software solutions can help in the management and maintenance of the building under consideration, both for the building owner and the building manager, they can confront the model with the current state of the building and thus eliminates the lengthy communication between the building manager and the building owner. Facility management elements can be managed more efficiently and since the software solution offers the possibility of alerts for both regular maintenance and sudden failures. It cannot happen that the maintenance of a given element will be lengthy. A barrier to implementation may be staff training, where it is necessary that the staff who will use the software solutions work correctly and efficiently in the software. It is also necessary to implement software solutions that have certain price ranges which form a cost item in the overall management and maintenance of the building. However, it must be noted that such a larger building cannot do without software support as the administration would be much more demanding.

6. Conclusion

This paper should point out that BIM technology itself can be used not only in the design, construction but also in the management and maintenance of a specific construction work. Facility management encompasses a wide range of options that can make it possible to set up the management and maintenance of a given construction work more efficiently. The actual management and maintenance procedures should be optimally set up in order to guarantee the operability of the construction work. During operation, the parameters of use and the purpose of the construction may change. As the use phase is the longest stage in the life-cycle phase of a construction, it is necessary to inspect the construction and, if necessary, remedy any deficiencies or defects in a timely manner.

In this case study, a model office building is used to show how a BIM model can be used for the management and maintenance of the building. The model of the office building itself should help the administrator to better orientate the building, to prevent, if not eliminate, faults in the building in a timely manner by means of timely inspections of the equipment located in the building. The case study in this paper should also show how this can be addressed and made easier in the occupancy phase nowadays by using digital technologies. Along with this, there are open questions and obstacles that should be resolved through research and then implemented into practice.

Acknowledgments

This paper was written in the course of the project VEGA 1/0626/22, KEGA 017TUKE-4/2024, VEGA 1/0228/24

References

1. Bryde, D., Broquetas, M., & Volm, J. M.: The project benefits of building information modelling (BIM). International journal of project management, 31(7), 971-980 (2013).
2. Haag, S., & Anderl, R.: Digital twin-Proof of concept. Manufacturing letters, 15, 64-66 (2018).
3. Errandonea, I., Beltrán, S., & Arrizabalaga, S.: Digital Twin for maintenance: A literature review. Computers in Industry, 123, 103316 (2020).
4. Boschert, S., & Rosen, R.: Digital twin-the simulation aspect. Mechatronic futures: Challenges and solutions for mechatronic systems and their designers, 59-74 (2016).
5. Schleich, B., Anwer, N., Mathieu, L., & Wartzack, S.: Shaping the digital twin for design and production engineering. CIRP annals, 66(1), 141-144 (2017).
6. Succar, B.: Building information modelling framework: A research and delivery founda- tion for industry stakeholders. Automation in construction, 18(3), 357-375 (2009).
7. Underwood, J., & Isikdag, U.: Emerging technologies for BIM 2.0. Construction Innova- tion, 11(3), 252-258 (2011).
8. Borrmann, A., König, M., Koch, C., & Beetz, J.: Building information modeling: why? what? how? (pp. 1-24). Springer International Publishing (2018).

9. Yalcinkaya, M., & Singh, V.: Building information modeling (BIM) for facilities man- agement-literature review and future needs. In Product Lifecycle Management for a Glob- al Market: 11th IFIP WG 5.1 International Conference, PLM 2014, Yokohama, Japan, Ju- ly 7-9, 2014, Revised Selected Papers 11 (pp. 1-10). Springer Berlin Heidelberg (2014).
10. Lin, Y. C., Chen, Y. P., Huang, W. T., & Hong, C. C.: Development of BIM execution plan for BIM model management during the pre-operation phase: a case study. Buildings, 6(1), 8 (2016).
11. Funtík, Tomáš et al.: Building Information Modelling. Martin: Alfa. 206s. 978- 80- 89228-56-0 (2018).
12. CIFE Technical Reports [online.] Available at: http://cife.stanford.edu/Publications/ in- dex.html. (2007).
13. Somorová, Viera: Facility management in construction. Bratislava: STU. 978-80-227- 4720-2 (2017).
14. Kuda, František et al.: Facility management in a nutshell for professionals and laymen. Olomouc: Form Solution 50s. 978-80-905257-0-2 (2012).
15. Wernerová, Eva, Stanislav Endel, and Dagmar Kutá. "Implementation of the BIM method at the VSB-technical university of ostrava." International Journal of Engineering Research in Africa 47 (2020): 133-138. DOI: https://doi.org/10.4028/www.scientific.net/JERA.47.133
16. Wernerová, Eva, Kuda, Frantisek, Faltejsek, Michal."BIM as an effective tool of project and facility management." International Multidisciplinary Scientific GeoConference: SGEM 18.2.1 (2018): 195-200. DOI:10.5593/sgem2018/2.1/S07.025
17. Bosch, A., Volker, L., & Koutamanis, A.: BIM in the operations stage: bottlenecks and implications for owners. Built Environment Project and Asset Management, 5(3), 331-343 (2015).
18. Gao, X., & Pishdad-Bozorgi, P.: BIM-enabled facilities operation and maintenance: A re- view. Advanced engineering informatics, 39, 227-247 (2019).