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Building Information Modeling in Small and Middle Sized Buildings – Case Study

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Building Information Modeling in Small and Middle Sized Buildings – Case Study

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Abstract. Building Information Modeling (BIM) is a technology designed to improve and integrate all engineering aspects in the construction design process. Tools that incorporate the idea of BIM are becoming more advanced and also more popular. Available software solutions have already reached an assumable high level of development, but still are not as widespread and used on nearly as many construction projects as could be expected. Therefore the aim of this paper is to show the advantages and limitations of BIM by looking at projects of small and middle sized buildings from the conventional (2D) and BIM approach perspective. The study was based on the present projects executed in Poland and first-hand experience. In addition, the paper also presents a literature review and the results of a survey on the level of knowledge and scope of BIM technology application in Pomerania (Poland). The results of the study indicate that, against common opinion, BIM software is not only useful for large investments, but can also be recommended for the design of small and middle sized buildings. Presented case study reveals, that the use of BIM in smaller projects also provides significant advantages, especially in the context of time consumed for the design process.

1. Introduction

Building Information Modeling (BIM) is a concept stating that every aspect of the construction design process as well as its maintenance should be possible within one solution and with one common standard [1, 2]. This idea started in the early 1990's [3] and was developed by many manufacturers of software tools, that are available today sharing one common Industrial Foundation Classes standard (IFC). IFC laid the foundation for creating one common standard that enabled designers to cooperate and to share their projects, not limited by the software solution being used. Even though most, if not all, software programs that are designed to be used as BIM tools, use proprietary formats, all can export and import IFC files, so that a data (model) exchange is possible. With increasing model data that are implemented into BIM, the IFC format, with the .ifc file being a text document, is being updated on a regular basis. The current development of IFC is discussed in [2, 4].

Available software solutions, having been applied for almost 30 years now, have already reached an assumable high level of development, but still are not as widespread and used on nearly as many construction projects as could be expected. In comparison, the automobile industry has been using 3D solutions for decades and 2D solutions (2D CAD) are no longer in use. Nevertheless, in recent years more and more large construction projects have been designed and implemented with the help of BIM software [4, 5, 6]. The cost efficiency of such approach (using BIM can help saving up to 30% in the construction process [7, 8, 9]) was often one of the main arguments for implementing BIM and is presented i.a. in [10, 11]. Still for smaller projects, such as single-family house design or small offices or industrial facilities, ranging from as little as 100 sqm up to 1000 sqm, BIM has not been considered as worth the challenge of being implemented in small design offices [12, 13]. Although interior designers use very often 3D software, they usually only present in a visual way their designs to the investor. Therefore the primary focus of this paper is to show the advantages and limitations of BIM by looking at projects of small and middle sized buildings from the conventional (2D) and BIM approach perspective. The study was based on the projects executed in Poland in the years 2016 - 2018 and first-hand experience. In addition, the paper also presents a literature review and the results of a survey on the level of knowledge and scope of BIM technology application in Pomerania (Poland).

2. The scope of BIM application

Numerous applications of BIM technology in the building life cycle cause that the group of interested entities is large [12, 14, 15, 16]. These include: the ordering party (with public funds), a private investor, designer, contractor, facility owner, manager, and developer [17].

In the light of the current regulations, currently in Poland, there is a lack of the possibility of using electronic documentation, it is ordered to use paper version (there are some exceptions to this principle, e.g. the report on investment impact assessment on the environment, which is required in paper and electronic version) [13, 16, 18].

This approach is in contrary to the idea of large construction corporations that benefit from the development of technology, making projects and documents available in electronic form [19]. Currently in Poland, there are more and more programs and applications that have access to 2D and 3D documentation in their offer, thanks to which the information is transparent and permanently archived [20].

The use of BIM technology in European countries is very diverse [9, 13, 21]. European leaders and countries where BIM occupies a marginal position have crystallized over the years. Countries that introduced BIM models as the standard for public procurement are Norway, Finland, Denmark (2007), Netherlands (2012) and UK (2016) [6, 9]. Countries that have taken steps to popularize BIM in the public sector include France (2017), Spain (2018) and Germany (2020). Despite the fact that some European countries do not implement and do not promote the use of BIM, thanks to effective changes in the construction sectors of these countries, this technology is gaining popularity, which means that more countries recognize the need for its implementation. In Poland, there is also an increased interest in BIM technology as compared to the situation that took place a few years ago [4, 12, 13, 16]. However, the investments implemented with the use of BIM are still not numerous. The individual examples of public investments can be indicated, for which the contracting parties set specific requirements (described in the SIWZ – The specification of essential terms of the contract, OPZ - description of the subject of the contract or the content of the contract) related to the use of BIM. For example:

- the construction of the Józef Piłsudski Museum complex in Sulejówek (tender from May 2016),
- the thermomodernization of the buildings of the Jan Matejko Academy of Fine Arts in Krakow (tender from October 2016),
- the construction of the Cross-country Skiing and Biathlon Center in Szklarska Poręba-Jakuszyce (tender from March 2016),
- the modernization of the Building of the Institute of Thermal Technology at Nowowiejska 21/25 st. in Warsaw (tender from May 2016),

- the implementation of the task "A nearly zero-energy building of the Faculty of Architecture and the Faculty of Management Engineering (WAIWIZ) at the Poznan University of Technology" (tender from December 2016).

Apart from public investments, in recent years in Poland, several private investments were carried out, in which BIM technology was used. For a long time, BIM technology has been widely used by large construction and development companies, including Skanska S.A., Budimex S.A., Bilfinger Tebodin Poland Sp. z o.o. and Murapol S.A. The software applied to model information about the building used by Polish design offices, architectural work and some contractors in the course of the investment implementation include: Revit, Navisworks (Autodesk), Tekla Structures, Autodesk BIM 360 Team, BIM360 Field and BIM360 Glue Autodesk, BIM360 Plan.

Despite several spectacular examples of successful investments and a number of benefits resulting from the use of BIM technology, the scale of its implementation in Polish construction is small [12, 13]. In order to determine the level of knowledge and scope of BIM technology and the possibilities and limitations related to its implementation and application, the authors conducted surveys among entities operating in Pomerania (Table 1). The research was carried out in the first half of 2018 - 25 design and architectural studios, 3 private investors (development companies), 1 public procurer, 19 contractors of construction works, 1 company specializing in investment implementation management took part there.

Table 1. The level of knowledge and scope of BIM technology application in Pomerania (Poland)

The selected questions from the survey	**Design and architectural studios**	**Private investors (developers)**	**Public contracting entity**	**Contractors of construction works**	**A company specializing in investment management**
Does the company know the BIM technology and is aware of the possibilities and threats resulting from its use?	84% yes 16% no	67 % yes 33% no	100% no	47% yes 53% no	100% yes
Does the company use BIM technology?	32% yes 68% no	33% yes 67% no	100% no	26% yes 74% no	100% yes
Does the company plan to implement and use BIM technologies in the coming years?	80% yes 20% no	100% yes	100% yes	74% yes 26% no	BIM implemented and used

The results of the survey indicate that currently the vast majority of contractors are not able to undertake the project in BIM technology. Only 1/4 of the group of surveyed contractors uses BIM technology (some contractors/subcontractors are not even aware of its existence).

The extended results of the study also allow to state that BIM models are gaining popularity, especially among installation companies (specializing, among others, in ventilation, air conditioning and heating systems).

Representatives of the surveyed entities indicated the following possibilities and benefits resulting from the implementation and wide application of the centralized BIM information exchange system:

- a rational approach to the collection and consumption of stocks of building materials,
- the possibility of avoiding collisions in the execution of works, and thus improving the quality of performed works,
- the possibility of limiting the number of accidents in the course of works implementation,
- the possibility of increasing the number of clients cooperating with the company thanks to increasing the efficiency of operations,
- quick contact and better communication between the designer, contractor, investor, subcontractors, industry,
- quick access of involved entities to current information made available in the data cloud,
- increasing the possibility of predicting the threat, faster intervention and earlier preparation of the security system, which in the end contributes to the improvement of safety at the construction site,
- the ability to optimize technical, technological and organizational solutions for investments in terms of costs, time and functionality [22, 23],
- significant reduction of risk related to improper preparation and implementation of the project [24],
- the possibility of the investor identifying project limitations, modifying details, specifying solutions depending on individual expectations, thanks to a virtual 3D model that can be viewed at an early stage of the investment process.

3. BIM versus conventional approach

In order to understand the major differences in the way the required project documentation is conventionally created and how it is created using BIM, it is necessary to look at both of those approaches a little closer (Figure 1, Figure 2).

It should be emphasized that, at the present moment, the maintenance with the use of BIM software is not fully implemented and therefore this comparison is targeted at a final result in the form of building documentation (mainly drawings and material reports) that is required on site in order to construct the designed building. Furthermore, road design that is moving towards similar solutions as BIM software, sometimes also referred to as BIM in civil engineering, was not taken into consideration in this comparison.

In small and middle sized buildings most of the design work is concentrated on the architectural and structural design. Depending on the country and size of the building sometimes these are the only two, by regulations, required designs that have to be presented to authorities in order to get a building permit.

Beside formal, but not design related work, the following elements have to be designed, in order to obtain the necessary project documentation:

- architectural design resulting in the form of drawings of views, floor plans, cross-sections and details,
- structural analysis resulting in required cross section of members, material properties, dimensions of elements (walls, slabs, columns) and required reinforcement of concrete presented in the form of floor plans drawings, cross-section and details,
- reports presenting the quantities of material used in the form of lists.

It should be mentioned that very often visualizations in the form of rendered images of the designed building and its parts are requested by the investor at the early stage of the design process – it gives the investor better understanding of how the final building will present itself.

Looking at the steps that have to be performed (Figure 1, Figure 2) it might seem that the differences between the two analysed approaches are minimal but the differences are visible in the work load and required time to perform these steps. The biggest advantage of the 3D model comes into play, when modifications are required. Modifications – moving walls, changing the placement and size of openings, changing ceiling heights, etc. are some of the most cumbersome, but yet very often occurring parts during the design process because no matter how small these changes may seem they require in most cases drawings of plans, sections and view to be redone.

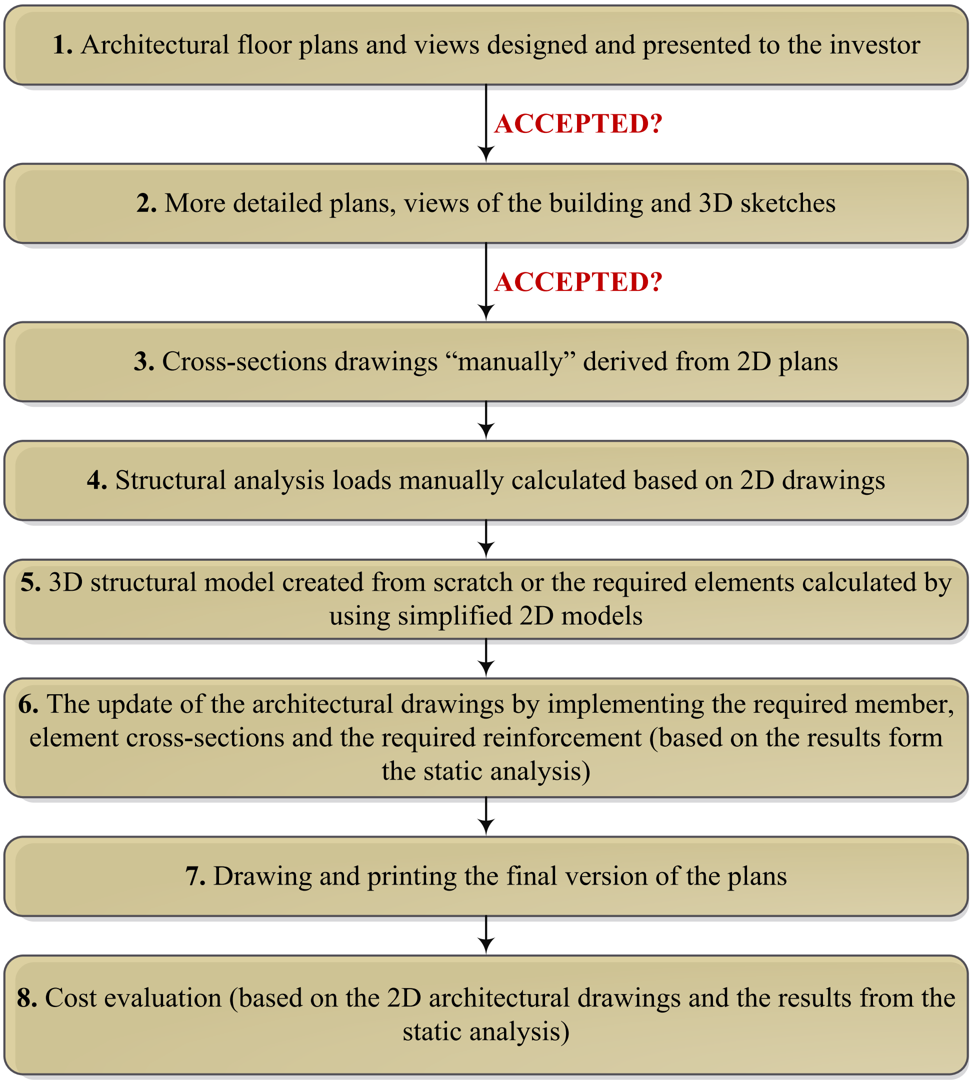

Figure 1. Necessary steps in creating project documentation according to the conventional 2D approach

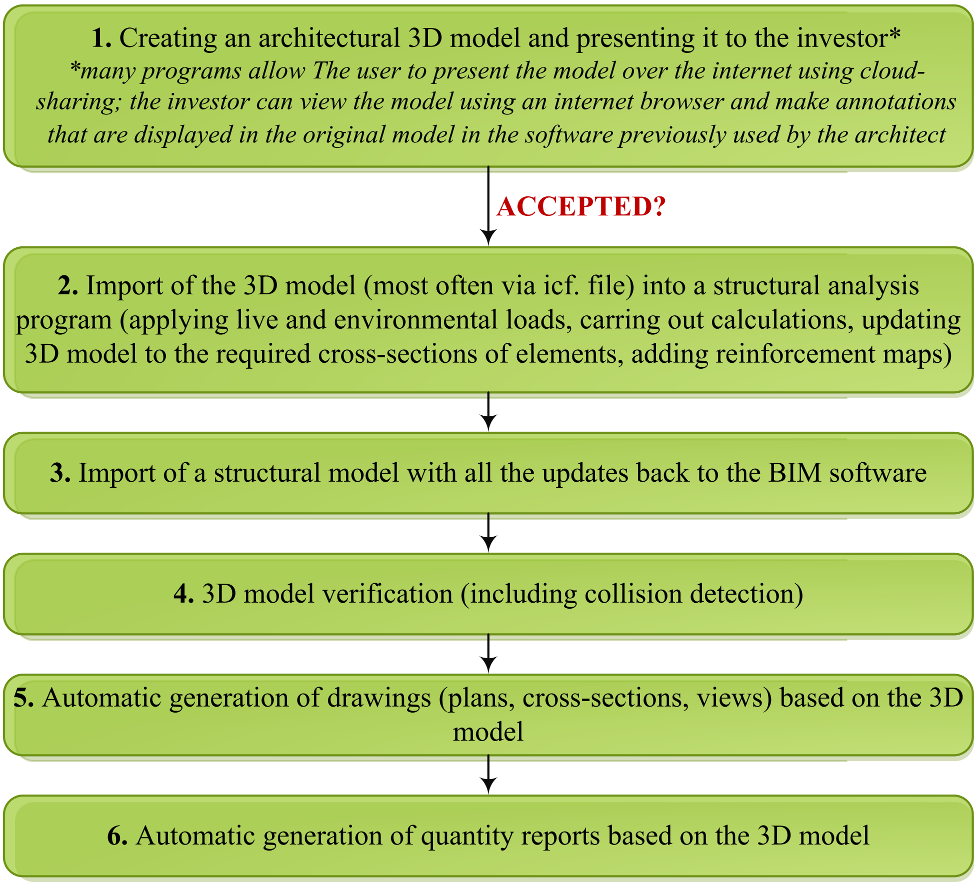

Figure 2. Necessary steps in creating project documentation using BIM software

4. Application of BIM – case study

In the following case study two real-world construction projects have been analysed in terms of workload measured in time (hours) necessary to carry out different stages of the design process. Both analysed buildings have been designed, in the first step, in a conventional manner by using 2D CAD design (Autodesk Autocad), then both models have been designed as a 3D model in a BIM environment (using Allplan). The first building was a commercial building (dental clinic) and has been designed as a cast in place monolithic reinforced concrete structure. It consisted of a basement and 3 stories (the third storey being an attic). The second building was a residential building that consists of 3 segments with 2 stories and a common garage.

4.1. The comparison procedure

For the comparison of the two above mentioned approaches, the following general stages of the design process were performed (see Table 2) and the time required for these stages is presented in Table 3. Due to the requirements of the design stage, there have been some differences in the level of detail between the 2D drawings compared to the 3D model. Therefore to keep the comparison as accurate as possible these differences have been taken into account - the early stage conceptual drawings have been excluded from the comparison. For both presented cases the performed steps were almost identical. The major tasks that have been performed during different stages of the design process depending on the approach are presented in Table 2.

In case of stage 7 (Table 2 - structural calculations), it has been taken into consideration whether, depending on the method used, the input material enabled the structural engineer to import any data into the structural analysis software or if everything had to be done from scratch.

In order to distinguish the differences between both of the approaches, in Table 2 an overview of the stage related tasks is shown. Depending on the project these steps may slightly vary in their order and extent.

Table 2. The task performed during different stages of the design process depending on the approach

Stage	Conventional 2D approach	3D BIM approach
1	Creating basic drawings that present the general design	Creating a complete 3D model with all elements (description, doors, windows, furniture, etc.)
2	Creating more specific drawings, assigning general functions to rooms	
3	Calculating "manually" required space and numbers of steps, creating drawing of top view of the stairs	
4	Drawing windows and doors by defining height, dimensions and form (material, division, etc.)	
5	Adding a detailed description of rooms and measuring room dimension, adding room equipment (furniture)	
6	Based on existing drawing creating drawings of elevations and roof and cross-sections	
7	Creating from scratch a model for structural design and performing required calculations	Importing the 3D model via the IFC format for the structural analysis and performing required calculations
8	Verifying the assumed dimensions of structural elements as presented in the drawings, creating additional drawings for structural elements (e.g. foundations with reinforcement, slabs reinforcement)	Verifying assumed dimensions in the 3D model, adding additional elements (reinforcement, etc.)
9	Manually carrying out calculations for quantities of major elements (walls, slabs, insulation materials, doors, windows, etc.) based on the structural design and architectural drawings	Generating automatically quantity reports
10	Printing drawings and reports from previous stages	Printing drawings (drawings require sometimes a little attention and "fine tuning") and reports from previous stages

In Table 3, the time required to perform the tasks within every stage is presented. It should be noted that the time presented only refers to the execution of the pure designing work performed with the use of software – preparation and manual sketches. Discussions with the investor and similar activities have not been taken into account. Because both presented models turned out to be similar in time required to perform the separate tasks, the presented values refer to the average (arithmetic mean) time in hours (values have been rounded to full hours). The presented difference *D* has been calculated as follows:

$$D = \frac{t_{3D} - t_{2D}}{t_{2D}} \bullet 100\% \qquad (1)$$

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where:
D – difference in time consumed [%]
t_{2D} – time consumed at performing steps during conventional approach [h]
t_{3D} – time consumed at performing steps during BIM approach [h]

Table 3. Time comparison for both approaches and stages presented in Table 2

Stage	Conventional 2D approach t_{2D} [h]	3D BIM approach t_{3D} [h]	Difference D [%]
1	4	24	-45
2	12		
3	2		
4	4		
5	6		
6	16		
7	14	10	-29
8	8	6	-25
9	8	2	-75
10	4	4	0
TOTAL	78	46	-41

5. Results and discussion

The results of the survey indicate that the use of BIM saves a lot time required to perform design related tasks. In the compared stages 41% of the total time consumed could have been saved by the use of BIM software, which corresponds to 32 hours or 4 days. Looking at the problem from the perspective of the use of BIM (according to the data presented in Table 3), if the conventional 2D approach would have been used as reference point, it would mean that switching from BIM to a conventional approach requires almost more than 70% of extra time. In this comparison modifications at different stages of the design process have not been considered, but it can be assumed that it would be in favor of the BIM approach.

Looking at the presented results it may wonder why BIM isn't the most commonly used approach among design offices, big ones as well as those small ones. The answer can vary from case to case, but the major reasons are:

- BIM is not so well known to the designers,
- classic 2D approach is commonly spread and easily accessible,
- 2D approach is commonly used at higher education level, graduates are familiar with it,
- BIM tools seem at first glance more expensive,
- data exchange between design offices is not always possible with BIM, whereas 2D is always possible,
- the learning curve for BIM software is steeper all the way as compared to 2D approach,
- BIM requires a 3D approach and not all standards (EC2, EC3, etc.) provide complete solutions for 3D,
- at the present moment it is not possible to skip the 2D approach entirely by switching to BIM, still some elements require 2D tools, so/thus using only BIM is not possible,
- BIM tools still haven't reached (as by designers requested) the required level in order to make the 2D approach obsolete,

- not all branches have access to the same variety and quality of BIM tools.

Introducing BIM approach to education would undoubtedly guarantee future graduates being familiar with BIM and would be a highly influential step in the implementation of BIM to the designers realm.

6. Conclusions

The aim of the article has been to show the advantages and limitations of BIM by investigating projects of small and middle sized buildings at its present level of development. The results of the study indicate that the process of BIM implementation in Poland is still in the initial phase, and in practice faces many barriers and limitations. However, some construction companies decide to create technical departments and innovation teams specializing in BIM technology. In a wider perspective, the use of BIM technology builds a good image of the company and is an element of competitive advantage in the construction market. Large companies carrying out construction projects emphasize that thanks to visualizations, schedules and cost estimates (4D and 5D dimensions) and multi-aspect simulations and analyses, they are able to better plan the work, which contributes to shortening their execution time, and thus greater customer satisfaction, increased profit and possibilities to continue cooperation.

Representatives of large construction companies emphasize that the use of BIM technology brings spectacular results primarily in the implementation of large and highly complex objects. In practice, however, one can find implementation examples of smaller investments and positive effects resulting from the use of BIM at the stage of conception, implementation and management of the construction process and operation of the facility.

According to popular and wide-spread opinion, major companies with large-scale projects are the only ones to profit from BIM, however this perception should be verified. Presented in the article case study shows, that the use of BIM in smaller projects also provides significant advantages, especially in the context of time consumed for the design process.

References

[1] C. Eastman, P. Teicholz, R. Sacks, and Kathleen Liston, “Enterprise Learning Solutions: BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers and Contractors 2nd Edition,” 2011.
[2] T. Ganbat, H.-Y. Chong, P.-C. Liao, and Y.-D. Wu, “A Bibliometric Review on Risk Management and Building Information Modeling for International Construction,” Adv. Civ. Eng., Article ID 8351679, 2018.
[3] IFC - Where it all started - The End of Babel - Part 1/2. IFC promotional video.
[4] A. Foremny, “Wykorzystanie BIM w fazie wykonawczej przedsięwzięć budowlanych,” Mater. Bud., vol. 12, no 496, pp. 82–83, 2013.
[5] C. Boton and D. Forgues, “Practices and Processes in BIM Projects: An Exploratory Case Study,” Adv. Civ. Eng., Article ID 7259659, 2018.
[6] A. Porwal and K. N. Hewage, “Building Information Modeling (BIM) partnering framework for public construction projects,” Autom. Constr., vol. 31, pp. 204–214, 2013.
[7] E. Plebankiewicz, K. Zima, and M. Skibniewski, “Analysis of the First Polish BIM-Based Cost Estimation Application,” Procedia Eng., vol. 123, pp. 405–414, 2015.
[8] K. Zima, “Modelowanie informacji o budynku w procesie szacowania kosztów,” Zesz. Nauk. Politech. Rzesz. Bud. Inż. Śr., vol. 58, no 3/III, pp. 289–296, 2011.
[9] R. Eadie, M. Browne, H. Odeyinka, C. McKeown, and S. McNiff, “BIM implementation throughout the UK construction project lifecycle: An analysis,” Autom. Constr., vol. 36, pp. 145–151, 2013.
[10] W. Lu, A. Fung, Y. Peng, C. Liang, and S. Rowlinson, “Cost-benefit analysis of Building

Information Modeling implementation in building projects through demystification of time-effort distribution curves," Build. Environ., vol. 82, pp. 317–327, 2014.
[11] S.K. Lee, K.-R. Kim, and J.-H. Yu, "BIM and ontology-based approach for building cost estimation," Autom. Constr., vol. 41, pp. 96–105, 2014.
[12] M. Apollo, E. Miszewska-Urbańska, and B. Grzyl, "Building Information Modelling as an opportunity and risk for stakeholders involved in construction investment process," Procedia Eng., vol. 196, pp. 1026–1033, 2017.
[13] M. Juszczyk, M. Výskala, and K. Zima, "Prospects for the use of BIM in Poland and the Czech Republic – Preliminary Research Results," Procedia Eng., vol. 123, pp. 250–259, 2015.
[14] S. Bhuskade, "Building Information Modeling (BIM) ," Int. Res. J. Eng. Technol. IRJET, vol. 2, no 2, pp. 834–841, 2015.
[15] D.G. Lee, J.-Y. Park, and S.-H. Song, "BIM-Based Construction Information Management Framework for Site Information Management," Adv. Civ. Eng., Article ID 5249548, 2018.
[16] A. Anger, B. Lisowski, W. Piwkowski, and P. Wierzowiecki, "Ogólne założenia procesu wdrażania BIM w realizacji zamówień publicznych na roboty budowlane w Polsce," Przegląd Bud., vol. 5, 2015.
[17] B. Grzyl, M. Apollo, and E. Miszewska-Urbańska, "Building Information Modeling : analiza zakresu i stanu implementacji w polskiej branży budowlanej," Autobusy Tech. Eksploat. Syst. Transp., vol. 17, no 12, 2016.
[18] K. Orlińska-Dejer, "BIM w przetargach publicznych – analiza wybranych postępowań przetargowych," Mater. Bud., vol. 10, 2017.
[19] E. K. Zavadskas, J. Antucheviciene, T. Vilutiene, and H. Adeli, "Sustainable Decision-Making in Civil Engineering, Construction and Building Technology," Sustainability, vol. 10, no 1, pp. 14, 2018.
[20] A. Tomana, "BIM – Innowacyjna technologia w budownictwie. Podstawy, standardy, narzędzia," I. Builder, 2016.
[21] A. Bradley, H. Li, R. Lark, and S. Dunn, "BIM for infrastructure: An overall review and constructor perspective," Autom. Constr., vol. 71, pp. 139–152, 2016.
[22] K. Zima, "Impact of information included in the BIM on preparation of Bill of Quantities," Procedia Eng., vol. 208, pp. 203–210, 2017.
[23] E. Plebankiewicz, K. Zima, and M. Skibiniewski, "Construction cost and time planning using BIM-based applications," Creative Construction Conference, pp. 537–545, 2015.
[24] B. Grzyl, and A. Kristowski, "BIM jako narzędzie wspomagające zarządzanie ryzykiem przedsięwzięcia inwestycyjnego," Mater. Bud., t. 6, pp. 52–54, 2016.