POLLACK PERIODICA
An International Journal for Engineering and Information Sciences
DOI: 10.1556/606.2020.15.1.15
Vol. 15, No. 1, pp. 158–168 (2020)
www.akademiai.com

THE POTENTIAL OF BUILDING INFORMATION MODELING IN CIVIL ENGINEERING

[1] Jana SMETANKOVÁ[*], [2] Peter MESÁROŠ, [3] Tomáš MANDIČÁK

[1,2,3] Department of Construction Technology and Management, Faculty of Civil Engineering
Technical University of Kosice, Vysokoskolska 4, 042 00 Kosice
e-mail: [1]jana.smetankova@tuke.sk, [2]peter.mesaros@tuke.sk, [3]tomas.mandicak@tuke.sk

Received 31 December 2018; accepted 6 July 2019

Abstract: Civil engineering industry represents important industry segment, which deals with building, performing and managing construction and business. In this sector, more and more pressure is generated for raising the effectiveness and productivity. Main tool, which supports the effectiveness and productivity, is process automation. Building information modeling represents intelligent process based on a model, which offers civil engineering specialists an overview and tools for effective planning, building blueprint, building management and infrastructure. Primary building information modeling goal is to create the uniform environment, which allows managing the life-cycle of building. Result of this work in enlisted environment is a multi-dimensional model, which carries all the information. This article deals with building information modeling issues, specifically with its dimensions and brings short description of each dimension and actual level of using the 5th dimension (cost estimating) in Visegrad Four countries. Level of 5D usage is demonstrated through surveys which were realized in Visegrad Four countries, and offers an overview of current implementation status in these countries.

Keywords: Automation, Civil engineering, Building information modeling, Dimension

1. Introduction

Change of lifestyle in modern society is reflected by increased rate of flexibility, productivity and technological development. These facts highly influence particular sectors of economy. Civil engineering sector supports the process automation, based on these facts. Important tool for raising the affectivity and productivity in civil

[*] Corresponding Author

engineering industry is Building Information Modeling (BIM). First mention of the BIM concept was recorded in 2002, but development of support tools began in the first stages of computer technology evolution. In 60th years of 20th Century, first commercial software applications were developed. These were constantly evolving; improving and currently a lot of software is known that represents complex support tool for planning, management and control of building throughout its life-cycle.

There exist a lot of definitions for building information modeling. Most known definitions are following: Kreider and Messner [1] define BIM as a tool that brings positive influence on digital skills enhancement. BIM represents assets delivery process through structured digital skills that are free for all participants [1].

Hardin [2] defines BIM as a revolution technology and process, which changed a way of creating a blueprint, realization and management of building [2].

BIM brings a lot of technical benefits and introduces innovative and integrated work platform that improves productivity and sustainability throughout the whole project life [3].

Based on these definitions, the main BIM goal is to create a uniform environment - a model with whom it is possible to control and manage the life-cycle of building. BIM brings a lot of functions and presents helpful and complex tool for building production management.

Created model is a multi-dimensional model that carries graphic and non-graphic information marked as dimensions. Due to BIM principles, there exist 7 established dimensions:

- 3D - geometry;
- 4D - time;
- 5D - costs;
- 6D - sustainability;
- 7D - facility management (see *Fig. 1*, dimension of BIM) [4].

–

– *Fig. 1* Dimension of BIM (Source: Author's own processing)

3rd dimension - geometry is visible part of a model, because it represents graphic data. This dimension is a model manual, which allows detecting conflicts, project/model visualization and supports prefabrication [4].

4th dimension is a time-planning of construction site. 4D allows visualizing, managing and controlling processes during the life-cycle of a project. Main benefit of this dimension is optimization of activities, all deliveries, storage, etc. [4].

4D allows better control; detect conflicts and changes that occur during the project continuance. Also it offers methods for management and visualization of information [4].

Important part of a project is creating a construction budget. 5th dimensions allow budget monitoring and cost analysis. It is important to set the price of a building, additional costs (including profit), during realization of a building [5].

6th BIM dimension is used for assessment of energetically effectiveness during project and operational phase of the project. Dimension allows understanding the building activity and defining a strategy focused on optimizing the energy consumption of the building [4].

7th dimension is a tool for collecting relevant information connected to maintenance and management of a building and its facilities during the life-cycle. Dimension offers important information about the management and maintenance of buildings [4].

In the construction industry, we are faced with the requirement to establish the facts of existing buildings. Laser scanning technology is used for this purpose. Laser scanning creates a cloud of points that can be implemented and incorporated to the BIM environment. This model is characterized by high precision [6].

2. Methodology

BIM is a progressive tool, however the level of BIM implementation is very low, and some countries even do not use this technology. An effort to implement BIM into processes differs in each country. Some countries use BIM, but in the majority, it is still in construction planning phase - the technology serves as a project tool. Implementation is very low in time and cost planning. For pricing and cost management, software applications without BIM are used. The level of using BIM tools in civil engineering industry is mirrored by a survey that deals with current status of implementation.

2.1. Research areas and objectives

Based on problem definition, main research areas were set. Research is based on analysis of surveys focused on 5D implementation - 5D in cost estimation of building production in selected countries. Based on this fact, main research goal was set - to make an overview of implementation 5D (BIM) in Visegrad Four (V4) countries, and also partial goals were set, as stated below:

- to specify the benefits of 5D BIM;
- to bring the overview of software applications in context of 5D;
- to bring the overview and comparison of current state in BIM 5D implementation in selected countries - Visegrád Four.

2.2. Research processing

It is important to do several research tasks to achieve the research goal. In first step, it was necessary to explore several studies and survey that deals with this issue. Collected data and results were classified by selected regions and subsequently analyzed. The result of this research was theoretical 5D analysis and an overview of software applications that allows 5D model creating and actual status of BIM implementation in cost estimating process in Visegrad Four countries.

3. 5D - cost estimating

Success of each project depends on exact cost estimation. There exists a lot of factors that causes cost overrunning, whether it is fault definition of starting costs, unpredictable technical problems, missing or badly defined work range, changes, outside factors, etc. [7].

5D data model brings a lot of benefits in each project phase, that are visible in raising the safety level and lowering the cost usage. In project phase, 5D data model brings following benefits:

- accurate conflict analysis through creating various construction animations, what removes concept deficiencies and improve constructing, or deficiencies are totally removed;
- improving communication and limitation of failures, that can lead to lowering productivity and team-work effectiveness;
- ensure quality and cost-effective building process - planning coordination, conflict analysis, blueprint optimization and planning evaluation, calculations, process planning etc. [8].

Realization phase represents an important part in the life cycle of an object. In this phase, 5D data model can significantly improve effectiveness, transparency and cooperation. The logistic/material/product/machines/work costs can be lowered by rejuvenating these activities. This data model allows participants to monitor building process, monitor immediate resource needs, visualize plans and reassess processes [8].

In usage phase, 5D offers all building information. Almost 80% of financial resources are used in maintenance phase - facility management. From this point of view, 5D data model is very helpful for lowering and effectively using financial resources [7].

Due to these facts 5D brings an option to automatically generate accurate quantity takeoffs automatic generate accurate quantity takeoffs (directly and immediately with high level of accuracy), specification life cycle cost, comparison of costs, provides the project team a detailed project, works with BIM libraries.

There were developed several software applications, that allows creating and working with 5D digital model. These applications allow creating calculations, budgets and bill of quantities. Pioneering countries in development these applications are USA (software INNOVAYA Visual Estimating Software). In Europe, applications that support BIM and 5D model creation are developed in Great Britain - Exactal COST X;

in Germany - Neveris Nemetschek; in Poland - BIM estimate; in Croatia - GALA Construction; in Hungary - Terc and so on (see *Fig. 2* for more software applications).

Fig. 2. Overview of software applications (Source: Author's own processing)

4. Implementation of the 5D - cost estimating in Visegrad Four

BIM represents modern, intelligent processes for facility management. BIM term is not new on the market, what documents raising level of implementation in civil engineering industry. A lot of countries has already started to use and support information modeling tools in its industry. Leading users are Nordic countries - Finland, Norway and Denmark. Quite high is the implementation level in Netherland, United Kingdom, France, Germany, Austria, Spain, USA, UAE, Middle-East, Asia, Australia, etc. These countries continuously implement BIM into its laws and standards and do researches about BIM implementation in civil engineering industry.

4.1. Slovakia

Slovak construction industry is constantly improving, what is shown on the level of occupancy. In 2017, occupancy has increased by 4.4%, so the capacity of construction companies is occupied on record-breaking 93% (2017) [9].

Implementation of BIM, which is low in Slovakia, would help the growth of civil engineering industry. One of main reason of slow implementation is an absence of technical standards implementing BIM. In 2013, BIM Association Slovakia was created, which is the first organization supporting BIM implementation into civil engineering industry. Continuously is BIM getting into awareness of professionals and they're starting to implement.

In Slovakia, surveys were realized in connection to BIM implementation. One of first surveys was realized in 2015 - BIM Crunch 2015 - Report. Following in 2017, exploitation and benefits of BIM in construction project management and in 2018, pre-research current state of BIM implementation in building production pricing, were realized. These results brought the conclusions in *Table I* [10], [11].

There was also conducted survey entitled impact of management decisions based on managerial competencies and skills developed through BIM technology on performance of construction enterprises. The survey has shown that BIM technology affects management decisions and the development of managerial competencies and skills. The survey confirmed the impact on cost savings and construction time [12].

Table I

Implementation of BIM in Slovakia - summary of surveys [10], [11]

TITLE	YEAR	RESULTS
BIM crunch 2015 - Report	2015	66% addressed companies did not plan to implement BIM in next 5 years, 25% respondents know BIM benefits, however, they did not plan to use BIM, 65% respondents did not know BIM,
Exploitation and Benefits of BIM in Construction Project Management	2017	75.2% companies do not use the BIM, 24.71% respondents are use BIM technology in construction project management, 89.34% cost reducing in construction project management, 87.56% increasing the quality of the document, the elimination of error project documentation, 75.36% increasing of financial control.
Current state of BIM implementation in building production pricing	2018	77.4% asked do not use BIM tools, 67.7% did not meet BIM tools, the most used tool in cost estimating is Cenkros (87.1%), but it´s not a BIM software solution, 12.9% use BIM tools but only for bill of quantities and only 6.5% use BIM for bill of quantities and the budget itself.

From these results it is clear that interest in BIM is raising, however building production pricing in Slovakia is realized through standard building works databases in CENEKON structure code or TSP. Currently, on the market are available software applications CENKROS 4, Kalkulus and Odis, but they cannot be evaluated as BIM software applications. More and more appears an effort to connect building production pricing and building information modeling, but currently it is not possible to state, that in cost estimating, BIM tools are used.

4.2. Czech Republic

Building industry in Czech Republic shows insufficient level of practical usage of BIM method. Main reason for slow level of implementation is an absence of technical standard information included in 3D model. In this country, an organization Czech BIM Council has been established for support the BIM implementation; it raises awareness and helps BIM implementation in building industry. Based on this fact, Czech BIM Council created manuals BIM Handbook (2013) [13] and BIM Handbook for investors (2018) [14]. Currently in Czech industry, BIM is used only for creating the 3D models,

but there exist some attempts to implement BIM into BIM Execution Plan (BIM-EP), what increases the level of usage and solving basic processes and methods BIM [15].

For support the increase of implementation in Czech Republic, on 25th September 2017, government has approved the document on 'Conception of BIM implementation in the Czech Republic' [16]. This document includes a plan of continuous BIM implementation in Czech Republic in years 2018 - 2027. The milestone in this period is 2022, when it is expected that regulation of using BIM for over-limit public contracts for building activities financed from public resources will be taken into account [17].

In 2015, a research was realized in field of BIM usage suppositions. On the research, architects, engineers, building companies owners and investors has attended. Conclusion from this research is a fact, that awareness about BIM method was relatively low between public professionals. Only 41% asked people had known about project realized with BIM method. Research brought interesting discoveries also about collecting information about BIM method. 42% respondents have actively participated on courses that raise competence, 8% have read about this issue in science literature and have heard about in on conferences. In 2015, only 19% respondents, mainly architects and constructers, actively used BIM. Main reason, why companies did not use BIM method, was the lack of knowledge (58%), insufficient client's demand (25%) and high costs for purchasing the needed software tools [18].

Analogical to Slovakia, also in Czech Republic the building production pricing is performed through building database, respectively TSP. Currently, in country mainly software tools Callida, Kros or BuildPower are used, but these applications are not supporting BIM [19], [20].

An innovation on Czech market is ASPE software, which introduces BIM software solution. This software is a tool for complex electronic building monitoring and management. ASPE offers data environment, which allows managing and viewing the building documentation in one place, with using of BIM. Software environment allows creating budgets, schedules, billings and changes during building [21].

The use of BIM is progressing in the Czech Republic and the implementation rate is expected to increase, as evidenced by the establishment of the BIM Implementation Plan in the Czech Republic. In the Concept of BIM implementation in the Czech Republic there are precisely defined steps and important milestones supporting the implementation of the technology.

4.3. Poland

In Poland, there are not created standard and laws for investments with BIM technology, however implementation of BIM is still moving forward. In 2012, union BIM Klaster was created, which deals with connecting building industry and information technologies. The mission of this organization is to support using the innovative technologies in building industry, through project support, propagation and implementation of innovative management ways, developing the relationships, cooperation etc. [22].

Success of BIM Klaster is shown by researches and survey, which were realized in Poland, in 2015. Preliminary research results (Michał Juszczyk, Miloslav Výskala,

Krzysztof Zima [15]) or in 2016, research realized by Polish Ministry of Infrastructure and Construction. Results of the researches are shown in *Table II* [18], [23].

Table II

Implementation of BIM in Poland - summary of surveys [18], [23]

TITLE	YEAR	RESULTS
Prospects for the use of BIM in Poland and the Czech Republic - Preliminary research results	2015	81 % of respondents admitted that they had heard about this concept, 23% respondents do use the BIM, 93% of the respondents understood the necessity to implement BIM in Poland, Plans for the implementation of BIM in the company - 17% respondents did not know about any plans to introduce BIM in their companies within the following 2 years, 17% said that there were no such plans, and only 9% stated that BIM would be introduced in their company soon.
Polish Ministry of Infrastructure and Construction - Current state of BIM implementation in building production	2016	until 68% design documentation is in paper form (30% - in dwg format, pdf format and other CAD format), 80% heard about BIM technology, but don´t have experience, 18% know the technology and apply its some solutions, 2% know the technology and apply it in full.

Increasing level of implementation is shown also by cost estimating in building production. In Poland, specialized software is used for pricing and calculation of building production, for example BIMestimate is the tool that supports building information modeling.

BIM estimate allows project planning and cost estimating process. Software works with BIM models in IFC format, by which it can presents various designs, calculate volumes, surfaces, lengths, it can detect contradictions and allows to create budgets and analyses [24]. The BIM methodology is increasingly used in the Republic of Poland and is expected to be expanded further.

4.4. Hungary

From V4 countries, Hungary is a leader in BIM implementation. Hungary is the first V4 country that has defined BIM Mandatory Requirements. Organization MABIM has been established and it actively participates on support the using of BIM in Hungary with the goal of its professional usage. MABIM participates on creating regulated limit for Hungarian building market with investments, projecting, building and building management. This organization created in 2018 the manual BIM Handbook [25].

Increasing level of implementation in Hungary is shown in all project phases. As stated in BIM Handbook, building information modeling is normally used in time

planning - 4D BIM and cost estimate, budget - 5D BIM. Usage through each phase is shown in *Table III* [26].

Table III

Use of BIM in individual phases time planning and cost estimate, budget [26]

Process	Phase						
	Project preparation and impact studies	Concept design and feasibility study	Authorization process	Creation plans	Tendering	Realization	Feasibility
Time planning (4D BIM)	normally used	normally used	normally used	normally used	normally used	normally used	unused
Cost estimate, Budget (5D BIM)	normally used	normally used	normally used	normally used	normally used	normally used	unused

As it is shown in *Table III*, BIM is often used in Hungary also in cost estimating. For pricing, except standard software applications (Kôvet, Kimmer Szofverfejlesztés), software applications supporting BIM are also used (Terc and STR Vision CPM) [27], [28]. These applications allow complex electronically monitoring and managing of the buildings - create budgets, analyses, schedules, etc.

5. Conclusion

Building information modeling represents an important automation tool in building industry. BIM increases digital skills and presents intelligent project management through the whole building life-cycle. Each of the participants realizes the effectiveness of this technology and they are trying to implement it more and more into each project phase. This article brings an overview of BIM implementation into building industry in selected countries. Article is focused mainly on implementation conditions, also on options of improvement managing and planning each phase of life-cycle, with emphasis on cost and economical aspect. Slovakia, Czech Republic and Poland are more and more developing initiative to implement BIM, but the standards are still missing in these countries. From V4 countries, only Hungary has exact BIM Mandatory Requirements. Currently, in Slovak and Czech Republic, for cost estimating in building production are used software that does not support BIM. An ambition to implement BIM into standards is still developing. Based on the survey, BIM represents an important tool that helps with deciding and realization of buildings, particularly cost estimating. Research shown the difference in BIM implementation in V4 countries, and from its result it can be concluded, that Slovakia is not a pioneer in this area.

Acknowledgements

This work was supported by the Slovak Research and Development Agency under the contract no. APVV-17-0549. The paper presents a partial research results of project VEGA 1/0828/17 'Research and application of knowledge-based systems for modeling cost and economic parameters in building information modeling'.

References

[1] Kreider R. G., Messner J. I. *The uses of BIM - Classifying and selecting BIM uses*, Ver. 9, 2013.
[2] Hardin B. *BIM and construction management: Proven tools, methods and workflows*, Wiley, 2009.
[3] Elmualim A., Gilder J. BIM: innovation in design management, influence and challenges of implementation, *Architectural Engineering and Design Management*, Vol. 10, No. 3-4, 2014, pp. 183–199.
[4] *All the BIM dimensions* - AXD Studio, Ch. 05, From 3D to 5D, http://www.axdstudio.com/portfolio/all-the-bim-dimensions/,(last visited 19 December 2018).
[5] *How to correctly and objectively appreciate the construction,* Bestselling economic and construction software in Slovakia, (in Slovak) https://www.kros.sk/blog/ako-spravne-a-objektivne-ocenit-stavebnu-zakazku-65308, (last visited 19 December 2018).
[6] Tkáč M., Mesároš P., Mandičák T. Terrestrial laser scanning - effective technology for creating building information models, *Pollack Periodica,* Vol. 13, No. 3, 2018, pp. 61–72.
[7] Venkataraman R. R., Pinto K. J. *Cost and value management in projects*, Wiley, 2008.
[8] Zűblin STRABAG, BIM. 5D® - We're building the future, BLOX, Copenhagen, http://www.bim5d.strabag.com/en, (last visited 20 December 2018).
[9] ASB, *Construction continues to grow, but caution is recalled* (in Slovak) https://www.asb.sk/biznis/stavebne-podnikanie/stavebnictvo-stale-rastie-ale-pripomina-sa-opatrnost, (last visited 19 December 2018).
[10] *66% Slovak construction companies not planning to use BIM over next 5 years*, 2015. http://bimcrunch.com/2015/12/report-66-of-slovak-construction-companies-not-planning-to-use-bim-over-next-5-years/, (last visited 20 December 2018).
[11] Mesároš P., Mandičák T. Exploitation and benefits of BIM in construction project management, *IOP Conf. Series: Materials Science and Engineering*, Vol. 245, 2017, Paper No. 062056.
[12] Mandičák T., Mesároš P., Tkáč M. Impact of management decisions based on managerial competencies and skills developed through BIM technology on performance of construction enterprises, *Pollack Periodica,* Vol. 13, No. 3, 2018, pp. 131–140.
[13] Černý M. *BIM Handbook* (in Czech) 2013, https://issuu.com/czbim/docs/bim-prirucka-2013-v1, (last visited 27 March 2019).
[14] Černý M. *BIM Handbook for investors* (in Czech) 2018, https://issuu.com/czbim/docs/bim-prirucka-pro-investory, (last visited 27 March 2019).
[15] Slanec M. *Concept of introduction of the BIM methodology in the Czech Republic*, (in Czech) 2017, http://www.bimfo.cz/Aktuality/Co-obsahuje-Koncepce-zavadeni-metody-BIM-v-CR.aspx, (last visited 20 December 2018).
[16] *BIM Implementation Strategy in the Czech Republic* (2017), https://www.mpo.cz/assets/cz/stavebnictvi-a-suroviny/bim/2019/3/Koncepce-zavadeni-metody-BIM-v-CR_EN.pdf, (last visited 27 March 2019).

[17] Fibiger J. *Construction 4.0*, (in Czech) 2017, https://stavba.tzb-info.cz/15752-stavebnictvi-4-0, (last visited 20 December 2018).
[18] Juszczyk M., Výskala M., Zima K. Prospects for the use of BIM in Poland and the Czech Republic - Preliminary research results, *Procedia Engineering*, Vol. 123, 2015, pp. 250–259.
[19] Zabranský J. Prices in construction, (in Slovak) 2018, https://cinnos;ti.urspraha.cz/zakladni-cinnosti-spolecnosti/ceny-ve-stavebnictvi/, (last visited 20 December 2018).
[20] *BIM got green in the Czech Republic* (in Czech) 2017, http://www.cegra.cz/4-novinka-1182- bim-dostal-v-cesku-zelenou.aspx, (last visited 20 December 2018).
[21] *Construction data warehouse* (in Czech), 2018, https://www.aspe.cz/cs/, (last visited 21 December 2018).
[22] *BIM Klaster*, 2018, http://www.bimklaster.org.pl/?lang=en, (last visited 21 December 2018).
[23] Pilecka E., Szwarkowski D. Use of technology building information modeling (BIM) in the design high building based on innovative approach design CAE/CAD, *Technical Sciences*, Vol. 20, No. 4, 2017, pp. 375–389.
[24] *BIMestimate*, 2018, https://bimestimate.eu/en/bimestimate-about/ (last visited 21 December 2018).
[25] MABIM, Hungarian BIM Society, (in Hungarian) 2018, http://mabim.hu/celjaink/, (last visited 21 December 2018).
[26] Zagorácz M., Szabó B. BIM - Handbook - Introduction to BIM modeling, (in Hungarian) 2018, http://lechnerkozpont.hu/doc/terbeli-szolgaltatasok-attekintes/lechner-tudaskozpont-bim-kezikonyv-1-kotet-1-kiadas.pdf, (last visited 21 December 2018).
[27] *TERC*, 2019, http://www.terc.hu/, (last visited 27 March 2019).
[28] *STR Vision CPM Software*, 2019, http://www.epitoipariszoftver.hu/, (last visited 27 March 2019).