Assessing the performance of the BIM implementation process: a case study

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Abstract
The article proposes a system of indicators for measuring the performance of BIM projects. Proposed indicators are divided into groups as follows: quantitative (cost and time related numerical values) and qualitative (verbally expressed measures recalculated to scores according to the proposed four-point rating scale). The metrics include the time and cost variations, the assessment of the organizational scale of BIM deployment, BIM competency granularity level, BIM capability level, BIM maturity level. In the case study, the proposed indicators are applied for evaluating the results of the construction project. The limitations and difficulties faced up during the project implementation were discussed, and the benefits of the application of the BIM methodology were revealed. The application of the proposed methodology is useful in assessing at which level the BIM is applied in construction projects and measuring the progress towards achieving project goals. The proposed methodology can also be applied for constant monitoring of the BIM implementation in construction projects.

Keywords: building information modelling, BIM adoption, construction projects, performance indicators, metrics.

Introduction

Building information modeling (BIM) is becoming increasingly popular in the architecture, engineering, and construction (AEC) sector (Vilutiene, Kalibatiene, Hosseini, Pellicer, & Zavadskas, 2019). Generally, BIM can be described from different perspectives. At the same time, it is Technology, Process, Policy, and Methodology for information management in a construction project during the whole project life cycle. The principles of BIM in the construction industry reflect and can be originated from product life-cycle management (PLM) used in the industrial sector. The experience of the BIM applications in different countries revealed that the BIM-related approaches offer a variety of solutions that can enhance co-operation in the construction project and the quality of delivered results (Succar, Sher, & Williams, 2012).

BIM incorporates software, and information processing procedures for designing, documenting, visualizing, and reporting building elements, that can improve data sharing and integrated information management (Arayici, Fernando, Munoz, & Bassanino, 2018; Barlish & Sullivan, 2012). It helps in planning and decision support (Ghaffarianhoseini, Tookey, Ghaffarianhoseini, Naismith, Azhar, Efimova, & Raahemifar, 2017), contributes to the increase of productivity and economic indicators (Jang & Lee, 2018), and enables cost management and value engineering (Park et al. , 2017). Such benefits applicable to all the disciplines involved, including civil engineering.

Research on the integration of BIM within structural engineering is still in its infancy with many gaps (Vilutiene et al., 2019). But the review of BIM literature reveals that scholars promote the benefits of BIM, as it contributes to the rise of the efficiency of the design and helps reducing changes due to more precise error detection (Yuan, Sun, & Wang, 2018); helps to find the balance between time-cost construction parameters and maintenance effectiveness with help of actual project information (Zadeh, Wang, Cavka, Staub-French, & Pottinger, 2017); and creates a spatial thought, perception and collaborative problem-solving in construction design (Miettinen & Paavola, 2018).

Since BIM is still developing and building processes are increasingly becoming automated, roles and competencies must be defined, also complex services require knowledge through multidimensional simulation, such as 3D, 4D (including time), 5D (including cost), and 6D (including Facility Management) modeling (Smith, 2014). Most important, what lots of benefits of BIM can be achieved only using the project teamwork and effective information management during the whole project life cycle (Pavlovskis, Migilinskas, Antucheviciene, & Kutut, 2020).

That is why the collected and arranged project data with appropriate solutions for information management is essential to ensure effective implementation at any BIM maturity level (Succar et al., 2012). The concepts of BIM, the BIM-based work methods, and technologies are being implemented in the construction sector companies. However, the benefits of BIM-based approach implementation and application efficiency have not yet been reliably measured (Succar et al., 2012). There is no single system of criteria appropriate for this purpose, and there is a lack of evaluation methods (Barlish & Sullivan, 2012; Succar & Kassem, 2015; Sanchez, 2016; Saoud, Omran, Hassan, Vilutienė, & Kiaulakis, 2017). With the above in mind, the present study aims to determine indicators for assessing the effectiveness of the BIM approach in construction projects.

The methodology includes the conceptual model and the indicators for the assessment of the BIM approach in construction projects. The applicability of the proposed methodology is verified in case study analysis. BIM application assessment methods like proposed in this study can support the selection of acceptable investment scenarios in BIM methodology-based projects and create the preconditions for managing the BIM implementation progress.

Literature review

BIM in planning

The BIM methodology can be used by building owners and facility managers to solve information security issues and ensure that accurate and reliable information on their property and projects is used during the planning, design, construction, and maintenance phases (Zadeh et al., 2017). Recent research emphasized economic benefit as one of the core benefits of using BIM methodology because it ensures efficient cost management and significant cost savings (Ghaffarianhoseini et al., 2017). BIM methodology improves the quality of information transfer between participants to ensure fast and reliable decision making, but Barlish and Sullivan (2012) identified, what the success of BIM-based project implementation depends on the size of the project, team proficiencies, team communication, and other factors. Park et al. (2017) proposed the BIM-based idea bank that would systematically collect data from previous projects with the possibility to reuse them and effectively create new ideas.

BIM in design

The use of BIM methodology gives the possibility for improved co-operation, a continuous improvement between design disciplines with fewer design errors and increased accuracy, conflict detection with a reduced number of requests for information, decreased reworks and inefficient changes on-site, building design optimization, and sustainability analysis (Jang & Lee, 2018; Liu, Meng, & Tam, 2015). Going further, Yuan et al. (2018) suggested using BIM as the main tool to interconnect design for manufacture and assembly (DFMA) processes creating a concept for parametric design, and improved construction process. Research made by Arayici et al. (2018) concludes, what productivity-based design requires a methodology that allows the integrated operation of several project participants who interact throughout the lifecycle of the object. This leads to a huge need for the integration of multi-type domain modeling and life cycle cost analysis (Rad, Jalaei, Golpour, Varzande, & Guest, 2021). The BIM used in modeling of n-Dimensional environment can increase building performance at the use stage, and the client could potentially benefit from alternative design simulations, environmental modeling, and sustainability analysis (Asl, Zarrinmehr, Bergin, & Yan, 2015).

BIM is used to evaluate project design alternatives and ensure energy efficiency and a lower carbon footprint (Gerrish et al., 2017; Habibi, 2017; Migilinskas, Balionis, Dziugaite-Tumeniene, & Siupsinskas, 2016). The data exchange between a building information model (BIM) and a building energy model (BEM) was investigated with the impact of architectural and technical design parameters on the dynamic modeling of building energy efficiency (Beazley, Heffernan, & McCarthy, 2017; Ahmed, & Asif, 2020), together with solar energy sources at an early stage of BIM-related mechanical electrical and plumbing (MEP) design for residential houses (Castro & Alvarado, 2017). BIM is used as a thinking tool for the conceptual design process, specifically for evaluating the electrical energy consumption (energy system) inside BIM (El Sayary, & Omar, 2021). Only very few models are being developed to evaluate the effectiveness of BIM for asset redevelopment solutions (Pavlovskis et al., 2020), for the refurbishment of buildings (Scherer & Katranuschkov, 2018;

Ustinovichius et al., 2018) or heritage architecture projects as historic building information modelling (HBIM) (Jordan-Palomar, Tzortzopoulos, García-Valldecabres, & Pellicer, 2018).

Although BIM is often considered a solution to many issues, delays and cost increases often occur during the course of the project. This may be due to insufficient attention to the problems of cooperation and information exchange of project participants during the implementation of BIM-based projects (Vilutiene et al., 2019).

BIM in construction

Uncertainties and risks are inherent in the construction due to the nature and environment of the construction projects. The reliable information in time becomes a crucial factor for the implementation of a construction project because, during planning, design, and especially construction, some decisions and actions directly influence the management of the property. These problems can be solved by outsourcing the BIM-based companies to help general contractors ensuring effective project management (Fountain & Langar, 2018) and by using the BIM methodology (Ghaffarianhoseini et al., 2017; Tucker & Masuri, 2018).

BIM is considered to be one of the best solutions to the mitigation of risks and challenges comparing with traditional working practices and the best practices in the construction industry (Abanda, Tah, & Cheung, 2017). BIM can help to identify and facilitate construction risks (Zou, Kiviniemi, & Jones, 2017), improve safety at works (Ding, Zhong, Wu, & Luo, 2016), refine production and construction processes, allow to make more precise quantity take-off and define requirements for materials. Modeling of parametric elements with algorithms can also help to prepare alternatives for possible solutions (Caetano & Leitão, 2019), installation design, and details for quality assurance during construction works. At the end of construction work, the BIM-based model must be updated and changed to an as-built BIM-based model and documentation ensuring reliable information transfer (Fountain & Langar, 2018).

The use of tools such as 3D models, 4D schedules, and 5D cost management can significantly simplify comprehension between participants during the construction stage, operation-maintenance stage, and even in the whole project lifecycle. Besides, it leads to risk mitigation, reduction of errors, fewer reworks, cost savings, and less amount of construction waste (Akanbi et al., 2018).

BIM in operation-maintenance

BIM is not only the great potential for the construction industry; most researchers identify many challenges in various BIM applications (Succar et al., 2012; Arayici et al., 2018; Turk, 2016). According to Zadeh et al. (2017), high-quality BIMs can create great potentials for FM practitioners. However, assessing the usefulness of delivered BIMs to building users is a significant challenge and requires additional research. Akanbi et al. (2018) provide a solution to support architects and designers who analyze the environmental impact of design decisions over some time. The proposed tool is helpful for demolition engineers who can carry out audits of used building materials. Tucker & Masuri (2018) state that BIM was considered a significant contribution to sustainable facility management.

BIM benefits are also reported in optimizing costs and managing the risks in the development process (Zou et al., 2017), in storing consistent information to ensure appropriate maintenance, in increasing the performance of the knowledge management and reuse in other projects (Ding et al., 2016). Jordan-Palomar et al. (2018) analyzed possibilities to use BIM as historic building information modelling (HBIM) to ensure effective use of combined solutions from laser scan clouds, spatial 3D modeling, and unique interconnected information data-base to improve heritage management. This ensures the possibility to loop the project life cycle process and get precise information for property management, digital design, and preservation.

BIM assessment solutions

Barlish & Sullivan (2012) analyzed BIM-based projects and proposed the model for evaluation of BIM benefits based on success level assessment. Limitations of criteria depend on BIM success goals, data measurability, data collectability, data comparability, and need with integration in a project management information system. The lack of an assessment model for the whole life cycle of the construction project and internal processes was identified by Yilmaz, Akcamete, & Demirors (2019). They suggested the theoretical four-point rating evaluation model for BIM assessment with analysis of BIM capability levels and BIM attributes.
BIM obstacles and limitations are reasons why BIM implementation is not spreading so fast in the construction industry (Succar & Kassem, 2015; Beijia, Jinming, Fumin, Yanxi, Quanze, Shenhao, & Yang, 2021). Most often reported main

reasons for limited BIM implementations are: the lack of standards and policies at country level (Smith, 2014; Succar & Kassem, 2015; Loyola, & López, 2018); lack of BIM-related aspects in contracts, lack of leadership, trust and motivation (Alreshidi, Mourshed, & Rezgui, 2017); low BIM demand for both small and large companies or even at country level (Miettinen & Paavola, 2018); heterogeneous, fragmented, and non-collaborative BIM-related experience (Loyola et al., 2018); lack of knowledge and BIM education (Ghaffarianhoseini et al., 2017) with a skeptical opinion regarding new information technologies (Jordan-Palomar et al., 2018); high investment cost for software, hardware or training, low level of BIM investment (Jyh-Bin, & Hung-Yu, 2019) with long pay-off period (Ali, & Gholamreza, 2020) and issues related to information interoperability and model data management during the whole project life cycle (Jang & Lee, 2018).

Undoubtedly, the BIM implementation process must foresee all needs of a project team, agreed responsibilities between project participants, arranged data and information management (Zadeh et al., 2017). Very important not to forget to evaluate performance during BIM project implementation with a certain evaluation of benefits/losses achieved by every project participant and collaboration approach (Alreshidi et al., 2017). Abdirad (2017) suggested dividing BIM evaluation metrics into three groups: quantitative metrics, qualitative metrics, and criteria-like indicators. Choi, Leite, & de Oliveira (2018) suggested using these groups of metrics: cost, schedule, dimensions and planning.

In most scientific articles, BIM metrics described as a kind of BIM application assessment in a project (Andriamamonjy, Saelens, & Klein, 2019), company, industry, or even country level (Succar & Kassem, 2015), but there is a lack of single unified system or list of criteria that are appropriate for assessing the BIM application efficiency. In the light of the above literature analysis, this paper aims to propose a system of criteria for assessing the BIM application efficiency and verifying the application in case study analysis. The proposed approach may be applied by the construction companies, and especially by those performing design-build contracts.

Methods

The research carried out in two stages (indicators and assessment methods presented in Table 1): *Stage 1*. The aims and objectives of the study formulated, the literature analysis performed, the system of indicators for assessing the BIM application efficiency selected, and methods for determining the indicators' values described.

Table 1. The set of indicators for the assessment of BIM application efficiency. (Self-Elaboration).

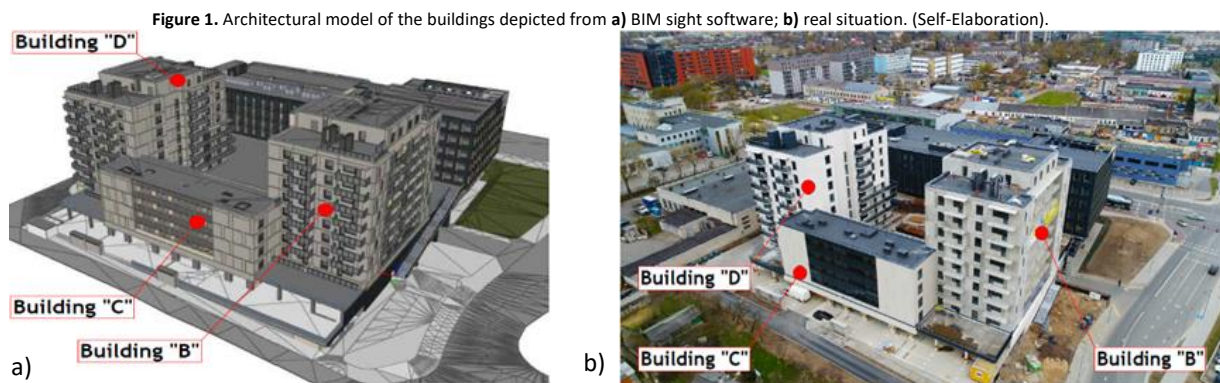| No	Indicators	Measuring units	Description
1	Project cost variance	%	$k_p = \frac{\sum P_p - \sum P_a}{\sum P_p} \times 100\%$, were k_p - percentage reduction in project costs, $\sum P_p$ – planned project budget, $\sum P_a$ - actual project budget
			0 Costs increased
			1 Costs decreased less than 5 %
			2 Costs decreased 10 % to 5 %
			3 Costs decreased more than 10 %
2	Project schedule variance	%	$k_t = \frac{T_p - T_a}{T_p} \times 100\%$, were k_t – percentage reduction in project execution time, T_p – planned scheduled project duration, T_a – actual project duration
			0 Duration increased
			1 Duration decreased less than 5 %
			2 Duration decreased 10 % to 5 %
			3 Duration decreased more than 10 %
3	Organizational scale of BIM deployment	points	BIM methodology is applied on:
			0 (0) – BIM methodology is not applied;
			1 (1) project level - only partial implementation of BIM for distribution between internal project participants;
			2 (2) division level - only partial implementation of BIM for internal information management in company division;
			3 (3) organization level - implementation of BIM for distribution between whole project participants (including external companies).
4	BIM competency	points	BIM methodology is applied:
			0 (0) at feasibility study level to identify and analyze initial possible alternatives to achieve project or/and Client initial aims/goals;

	granularity level		1	(1) at the evaluation level to identify most effective solutions meeting defined project or/and Client initial aims/goals;
			2	(2) in whole project at high level competence in preparation for certification and validation of competences;
			3	(3) at professional application and expert assessment level.
5	BIM capability level	points		BIM methodology is applied:
			0	(0) – BIM methodology is not applied;
			1	(1) only in the internal environment of the project;
			2	(2) in cooperation with other project participants (subcontractors, suppliers, manufacturers);
			3	(3) in an integrated environment for data interoperability with other data bases (WebBIM).
6	BIM maturity level	points		BIM methodology applicable to the exchange data and information:
			0	(0) – by using paper type documents with low level of automation;
			1	(1) - using electronic documents (2D and 3D) and local folder system;
			2	(2) - using electronic documents (2D and 3D) and common data base/library;
			3	(3) - electronic documents (nD) in the integrated information management according to requirements based on common data environment principles, also between participants and project disciplines/different BIM uses.

Stage 2. At this stage, the proposed indicators are validated by application to a construction project. Basing on previous research findings, the indicators for the assessment of the effectiveness of the BIM approach in construction projects have been chosen. Proposed indicators are divided into quantitative and qualitative. The quantitative indicators include cost variation and change in project duration comparing planned and actual durations. The set of qualitative indicators includes evaluation of the organizational scale of BIM deployment, BIM competency granularity level, BIM capability level, and BIM maturity level. A detailed description of the indicators for the assessment of BIM application efficiency, the scales, and assessment methods presented in Table 1.

Results

Description of case study object

For the testing of the proposed criteria system, the case study project "Zalgirio 135" in Vilnius (Lithuania) implemented using a BIM approach selected. The project includes three buildings: one business center and two dwellings (Figure 1). The total area of buildings is 15391 m^2, the area of the offices is 8400 m^2, and the area of dwellings is 6374 m^2. The BIM methodology in the analyzed project was applied at the design and construction stages. For technical design preparation, the project team included three structural engineers and one project manager. During the preparation of a detailed design project, the number of engineers increased to five.

Figure 1. Architectural model of the buildings depicted from a) BIM sight software; b) real situation. (Self-Elaboration).

Parametric models and information flows

Parametric 3D models were developed for architectural, water/sewerage, and HVAC project parts using BIMsight software. Figure 2 depicts the 3D model of building "B". The client performed a partial verification of the integrated model, and obvious errors were corrected. The systematic checking of the model was not performed. Software products, the data exchange formats, and data users on different stages of the project depicted in figure 3. At the concept stage, the project participants used .pdf and .dwg formats to transfer information to the design stage, and the designers used the AutoCAD software for the preparation of 3D conceptual drawings. During the design phase, the .pdf, .doc, and .rvt data exchange formats are used to transfer the information to the tender stage. The designers used the Autodesk REVIT software to prepare the 3D architectural drawings.

Figure 2. Architectural model and models of HVAC and water/sewerage systems of the building "B". (Self-Elaboration).
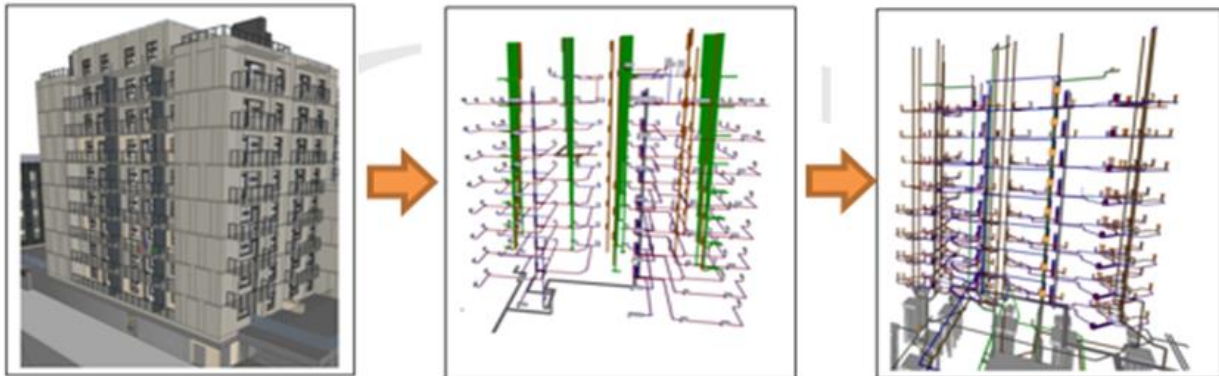
At the tendering phase, the .pdf, .rvt, and .ifc data exchange formats are used to transfer the information to the construction stage. During the construction stage, the .pdf, .rvt, .ifc, and .tbp data formats are used for exchanging data between the project participants and transferring the information to the handover stage. Autodesk REVIT, Tekla Structures, and Tekla BIM sight software were used at the construction stage. At the handover stage, the Autodesk REVIT software is used (Figure 3).

Figure 3. Information flows and data formats to transfer information. (Self-Elaboration).
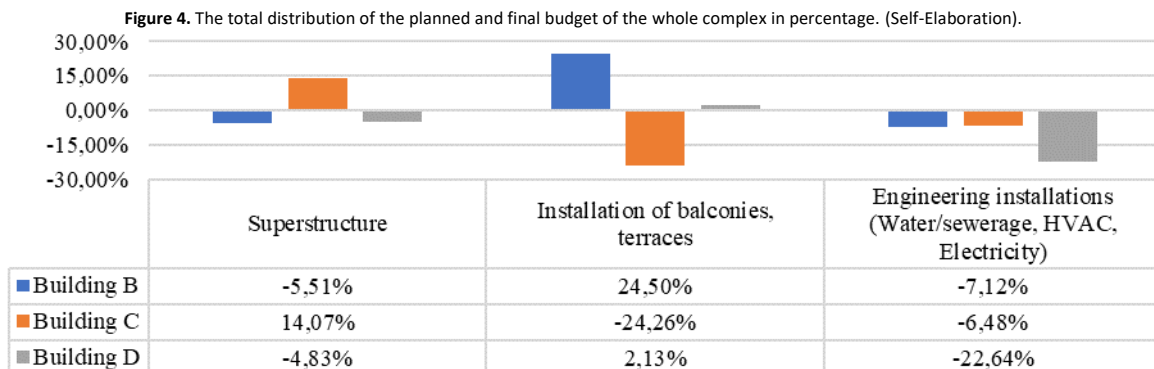

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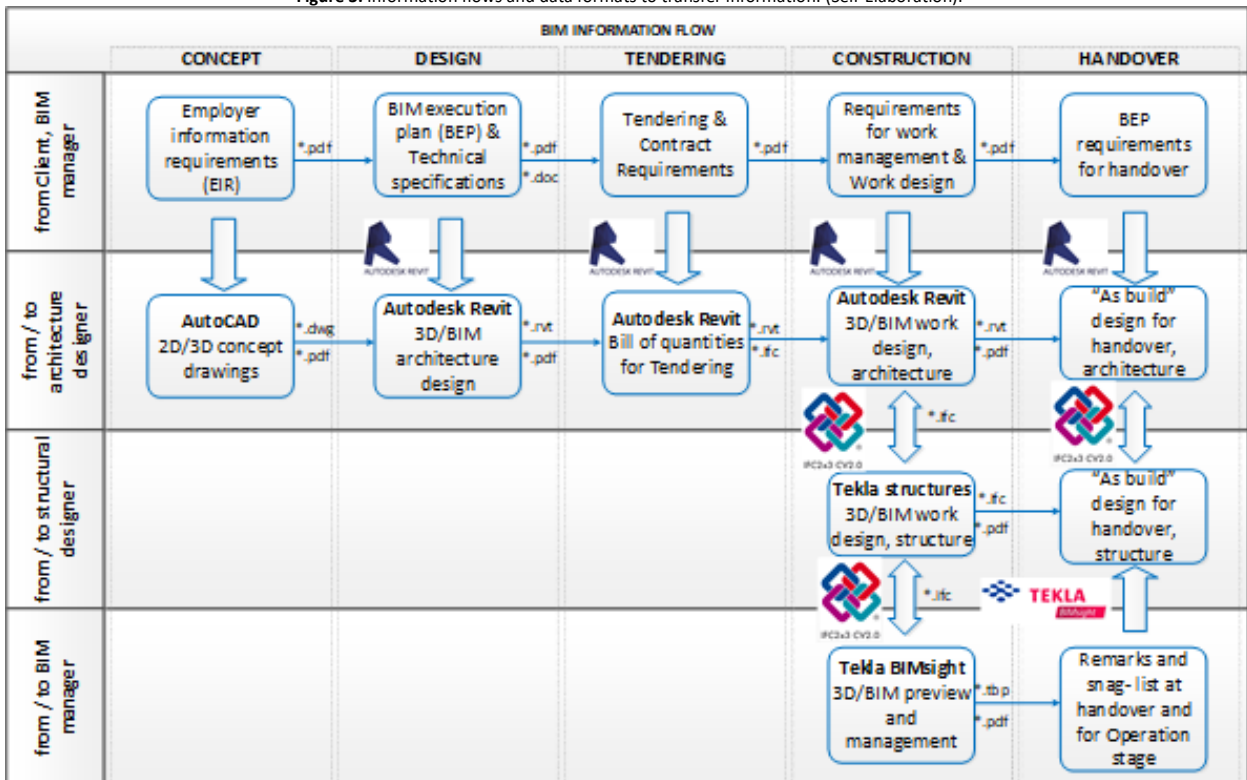
Benefits and challenging issues

Although the implementation of the BIM approach had obvious benefits and led to budget savings, the analysis of processes during the construction of case buildings revealed that the project team had to solve some challenging issues. The client made many changes during the preparation of the design project. This led to delays in the preparation of the detailed design project and led to the rise of the planned project price. The BIM approach allowed revealing the nonconformities in design solutions, like incorrectly designed heights at the exit of the "D" building, lack of a detailed solution for glazed facade windows installation in "C" building, and clashes in air supply systems in "B" building.

Project cost variance

The assessment of potential risks at the design stage, careful preparation of work estimates as well as the experience of similar work in other projects were the main reasons for the planned budget decrease during construction. The results of the case study analysis show that the project faced some challenges during the preparation of technical design project documentation, there were many changes initiated by the client during the course of the project. The change of design solutions during the construction phase affected the increase of the budget and rework in the design phase. Reduction or increase of planned and actual budgets of the buildings "B", "C" and "D" calculated as a percentage difference of the planned and actual budget. The reasons for the increased construction budgets of buildings "D" and "B" were changed design solutions of balconies during the construction phase.
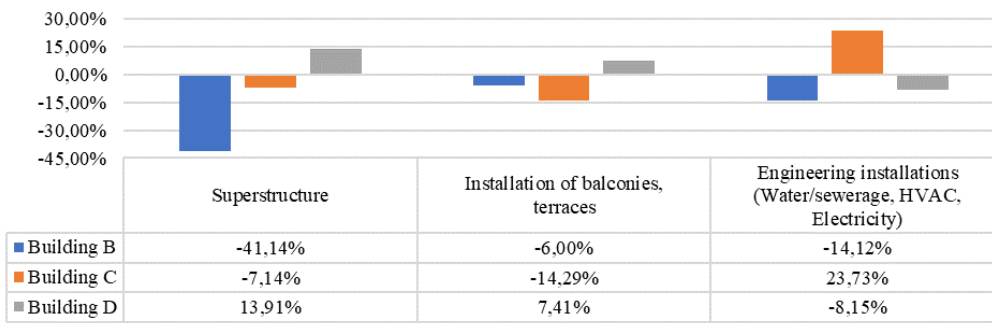
The reason for the increased budget in building "C" was an incorrect assessment of the construction costs of the superstructure. Figure 4 shows that the cost of construction work of superstructure was less than planned for the "B" and "D" building parts, which was respectively 5.51 % and 4.83 %, while the cost of construction of the "C" part has increased by 14.07 %. The budget for the installation of balconies and terraces was saved by 24.26 % for the "C" building, while the budget for the "B" and "D" buildings increased by 24.5 % and 2.13 %, respectively. The cost of internal engineering works was less than planned for all buildings, respectively for the "B" building actual cost decreased by 7.12 %, for the "C" building by 6.48 %, and for the "D" building by 22.64 %.

Figure 4. The total distribution of the planned and final budget of the whole complex in percentage. (Self-Elaboration).

	Superstructure	Installation of balconies, terraces	Engineering installations (Water/sewerage, HVAC, Electricity)
■ Building B	-5,51%	24,50%	-7,12%
■ Building C	14,07%	-24,26%	-6,48%
■ Building D	-4,83%	2,13%	-22,64%

Project schedule variance

Project schedule variance is calculated as a percentage change of the planned and actual construction durations of the buildings "B", "C", and "D". For example, the duration of the superstructure construction work was decreased in the case of "B" and "C" buildings by respectively 41.14 % and 7.14 %, while the duration of the superstructure construction work of the "D" building increased by 13.91 % (Figure 5). The reasons for the increase of duration were the same as discussed in part "Project cost variance"; specifically, the project client initiated the changes of design solutions in buildings during the construction phase. These changes affected the costs and duration of construction works. Meanwhile, the changes in superstructure solutions made in building "D" and engineering solutions in building "C" did not have a significant impact on the price, but the change in procurement and supply tasks prolonged the construction process, especially in the case of building "D", as it was built first.

Figure 5. The total distribution of the planned and final duration of the whole complex in percentage. (Self-Elaboration).

	Superstructure	Installation of balconies, terraces	Engineering installations (Water/sewerage, HVAC, Electricity)
Building B	-41,14%	-6,00%	-14,12%
Building C	-7,14%	-14,29%	23,73%
Building D	13,91%	7,41%	-8,15%

The calculated numerical values of the indicators were converted into points according to the proposed methodology and presented in Table 2. Arguments and discussion on the results of the evaluation of other indicators are provided in the next section.

Table 2. Results of the assessment of BIM application efficiency. (Self-Elaboration).

Indicators	Project cost variance				Project schedule variance				Organizational scale of BIM deployment				BIM competency granularity level				BIM capability level				BIM maturity level			
points	0	1	2	3	0	1	2	3	0	1	2	3	0	1	2	3	0	1	2	3	0	1	2	3
Building B								✓				✓	✓					✓				✓		
Building C	✓				✓							✓	✓					✓				✓		
Building D			✓		✓							✓	✓					✓				✓		

Organizational scale of BIM deployment

The organizational scale of BIM deployment was determined by assessing the level of BIM methodology is implementation in a construction company. The first level refers to the situation when BIM methodology implemented only at the project level, i.e. BIM used only for the distribution of models between the participants inside the project. The second level refers to the situation when BIM methodology is implemented for internal information management in the company division. The third level refers to the situation when BIM methodology is implemented at the organization level - BIM methodology used by the participants of the whole project (including external companies). In the analyzed case study project, the BIM methodology was applied mainly in the design process, where the representatives of the client participated. The situation refers to the third level of the organizational scale of BIM deployment according to the proposed methodology (three points given according to the proposed scale).

BIM competency granularity level

BIM competency granularity level was determined by assessing the expertise level of BIM methodology application in project and company. At the first level, the company assesses the possibilities to use BIM as a feasible alternative that enables achieving project or/and client aims. On the second level, the company uses BIM methodology and assesses the most effective alternative solutions meeting defined project or/and client aims. On the third level, the company assesses the possibility of using BIM as a high-level competence for certification. On the fourth level, the company uses BIM professionally and makes project benefit assessment at an expert level. In the analyzed case study project, BIM methodology was used at the feasibility study level according to the proposed methodology (0 points given according to the proposed scale). BIM tools were used for previews, access to the data, for review of potential errors, and project adjustments. The information obtained from the 3D model was used for the preparation of tendering.

BIM capability level

BIM capability assessed at three levels. On the first level, the BIM methodology is used only for internal project needs. On the second level, BIM methodology is used for cooperation between the project participants (including external companies such as subcontractors, suppliers). On the third level, the use of BIM methodology is based on the principles of a common data environment. In the analyzed case study project, the information exchange among the client representatives (construction team and designers) was organized using one server, so ensuring the storage of all relevant information in one place. Subcontractors have not received a 3D model and parametric information. They used paper drawings on the construction site. The described situation refers to the first level of BIM capability according to the proposed methodology (one point given according to the proposed scale).

BIM maturity level

BIM maturity level was determined by assessing the information exchange among the project participants. The lowest level of maturity refers to the situation when the project team uses electronic documents (2D and 3D) and the local folder system. A slightly higher level of maturity refers to the situation when the project team uses electronic documents (2D and 3D) and a common database/library. The highest level of maturity refers to the situation when the project team uses the electronic documents in an integrated BIM-based system and ensures information management according to the requirements and common data environment principles. In the case study project, the architectural and other engineering 3D models were supplemented with parametrical information partially. To ensure the smooth transfer of the design data through all project stages, all documentation was transferred physically. Drawings and other design documentation were shared by emails using five different data formats. The described situation refers to the first level of the organizational scale of BIM maturity according to the proposed methodology (corresponds to one points in methodology).

Conclusions

This paper analyses the problem of BIM adoption in construction projects and presents a new approach for a comprehensive assessment of BIM application efficiency. The proposed approach includes qualitative and quantitative indicators proposed to assess the effectiveness of BIM in the construction project. The criteria system includes an assessment of time and cost variations. The authors used few qualitative indicators previously described in other sources, like the organizational scale of BIM deployment, BIM competency granularity level, BIM capability level, BIM maturity level. This study proposes an original scoring system for these indicators and combines them in one model with quantitative indicators.

The presented case study illustrates that the criteria system is easily applicable and can help to assess the level of BIM adoption on design and construction phases. The results conclude that the proposed model helps to perform a deeper insight into a problem. It has been determined that the application of BIM methodology has helped to reduce the risks of the construction, to improve data exchange, and slightly decrease project duration and costs.

The proposed approach is helpful for the construction companies in managing the BIM implementation progress, and especially for those performing large-scale design-build contracts. By focusing on BIM application assessment in real-life situations, the proposed model is versatile and therefore can be applied for various project types, for the whole project, or the separate project life cycle stages. The authors believe the proposed methodological approach can contribute to the generation of specific procedures for the monitoring of BIM adoption in construction companies.

Acknowledgement

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