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ADOPTION OF BUILDING INFORMATION MODELING IN THE CONSTRUCTION PROJECT LIFE CYCLE: BENEFITS FOR STAKEHOLDERS

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Abstract
Introduction: Building Information Modeling (BIM) is characterized by potential benefits at many phases of the construction project life cycle. However, no comprehensive study has been conducted to evaluate the benefits of BIM adoption and implementation for project stakeholders in the Vietnamese construction industry context. **Methods:** This study aimed to identify and evaluate the benefits of BIM adoption and implementation in construction projects based on the perception of project stakeholders through data collection from 159 valid construction practitioners. The reliability and validity tests were performed to analyze collected data by SPSS 22 software. **Results:** The results demonstrated that four primary clusters of the project stakeholders received benefits when BIM was adopted in construction projects: architectural and structural design units (10 benefits), facility management units (8 benefits), contractors (6 benefits), and owners (6 benefits). These clusters accounted for 58.954%, 5.975%, 4.682%, and 3.736%, respectively, of the variance that characterized the benefits of BIM adoption. The findings indicated that ‘improve the quality of design drawings’, and ‘minimize conflicts/changes’ were the most significant BIM benefits for architectural and structural design units, whereas ‘convenient for managing project data’ and ‘easy planning and resource mobilization’ were the top benefits for facility management units. For contractors, ‘minimize construction errors’ and ‘construction cost saving’ were the most prominent benefits. Besides, BIM brought owners such striking benefits as ‘maximize project performance’ and ‘easier to choose investment options’.

Keywords
BIM, benefits, project stakeholders, construction industry, life cycle.

Introduction

Building Information Modeling (BIM) has been recognized as one of the most efficient technological initiatives in response to the challenges within the construction industry (Azhar, 2011). BIM technology makes it possible to create a digitally constructed accurate virtual model of a building. This technology can be used for facility planning, design, construction, and operation. BIM assists architects, engineers, and builders in visualizing what will be built in a simulated environment so that they could identify potential design, construction, or operational issues. BIM represents a new paradigm within the architecture, engineering, and construction (AEC) industry, one that encourages integration of the roles of all stakeholders on a project (Azhar, 2011). A BIM model characterizes the geometry, spatial relationships, geographic information, quantities and properties of building elements, cost estimates, material inventories, and project schedule (Azhar, 2011; Chan et al., 2018). This allows project stakeholders to efficiently collaborate throughout the project lifecycle (Oesterreich and Teuteberg, 2019; Saka and Chan, 2019). BIM can be viewed as a virtual process that encompasses all aspects, disciplines, and systems of a facility within a single, virtual model; it enables all construction project stakeholders to collaborate more precisely and efficiently than using traditional processes (Azhar, 2011). Team members are constantly refining and adjusting their portions in response to project specifications and design changes to ensure the model is as accurate as possible before the project physically begins (Carmona and Irwin, 2007). One of the primary reasons for BIM adoption is to achieve a proper balance between the project management triangle of scope (features & quality), cost and time (Olawumi and Chan, 2019a; Olawumi et al., 2018), which is one of the most important concerns in the (AEC) industry (Chan et al., 2019b).

Stakeholders can maximize benefits in terms of time, cost, and quality by implementing BIM in construction projects (Wong et al., 2009). However, it is not easy to achieve a right balance between these three factors for the construction projects, since so many strategies and solutions are needed to accomplish it, and innovation can be one of the possible solutions to strike a balance between these three factors (Chan et al., 2019b). Hence, BIM is a new technology in the construction industry, which is expected to deliver numerous benefits to the industry, such as initial conflict control in the designing (Azhar, 2011), project performance and quality enhancement (Succar, 2009), enhance collaboration among construction stakeholders (Kerosuo et al., 2015; Succar, 2009), effective construction process (Abd Hamid et al., 2018), operation and maintenance of buildings (Hoang et al., 2020), improve visualization of project execution (Haron et al., 2015), decision-making process enhancement (Azhar, 2011), effective construction cost (Abbasnejad and Moud, 2013).

Even though BIM has been used in the construction industry in Vietnam since the early 2000s, it is still not widely applied (Van Tam et al., 2021a). This is especially true for construction projects funded with state-managed capital, which makes up the majority of Vietnamese construction projects (Dao et al., 2020). Being aware of BIM benefits, Vietnam has set 2021 as the target year for adopting BIM for all governmental and large construction projects (Dao et al., 2021). Investors and construction firms initially recognized the benefits of adopting BIM after observing the trends of BIM technology adoption. Numerous design firms and contractors have gradually integrated BIM tools into practical projects ranging from concept design to construction management. However, in the Vietnamese construction industry, BIM implementation is very slow. Its slow adoption and implementation are caused by numerous barriers, of which lack of perceived benefits of BIM adoption is considered to have a key role in this regard (Van Tam et al., 2021b). Moreover, there has been no in-depth research in Vietnam to assess the benefits gained by construction project stakeholders when adopting and implementing BIM. Therefore, this study aims to identify and evaluate BIM implementation benefits in construction projects through data collection from construction practitioners who implemented BIM in Vietnam. Benefits have always been achieved through effective implementation, and vice versa. Hence, BIM benefits should influence construction industry practitioners to foster BIM implementation (Al-Ashmori et al., 2020).

Literature review

BIM has great potential for useful adoption at all stages of the project life cycle. This technology can be used by the owners to understand project needs, by the design team to analyze, design, and develop the project, by the contractors to manage the construction of the project and by the facility managers during operation and decommissioning phases (Bryde et al., 2013; Grilo and Jardim-Goncalves, 2010). BIM has been proved as a very beneficial approach in reducing uncertainties and improving the efficiency of the construction process (Van Tam et al., 2021b). BIM will provide potential beneficial project outcomes by enabling the rapid analysis of different scenarios related to the life cycle performance of a building (Schade et al., 2011). The study of Fallon and Palmer (Fallon and Palmer, 2007) explained that BIM is very useful in increasing the speed and utility of activities by enhancing the quality of scheduling and cost information throughout the project lifecycle; one of the most frequently observed benefits is increased utility and speed (Memon et al., 2014). Several significant BIM benefits were identified by Al-Ashmori et al. (2020) in Malaysia such as (1) increasing productivity and efficiency; (2) assessing time and cost associated with design change; (3) eliminating clashes in design; (4) improving multi-party communication and maintain synchronized communication; (5) integrating construction scheduling and planning, (6) identifying time-based clashes; and (7) tracking progress during construction. In Hong Kong, Chan et al. (2019b) identified 12 benefits of BIM implementation. They found that the most significant benefits are (1) better cost estimates and control; (2) a better understanding of design; (3) reduce construction cost; (4) better construction planning and monitoring; (5) improve project quality. In Vietnam, the study of (Hoang et al., 2020) assessed 12 BIM benefits; the top five significant benefits were determined as follows: (1) collaboration improvement; (2) more accurate information from a data-rich asset; (3) automatically updated model; (4) improved interoperability; (5) increased employees' productivity and efficiency. In Turkey, 41 benefits of BIM adoption were identified by Seyis (2019). The top benefits include (1) planning the tasks and responsibilities in a timely manner; (2) promoting collaboration and coordination in the early design phase; (3) automatic implementation of design changes into 3D CAD model; (4) decreasing uncertainties in the processes by clarifying risks; (5) reducing time variances in the processes.

The introduction and adoption of any new technological advancement, such as BIM, usually necessitates identifying and addressing the factors that may affect the adoption by project stakeholders in order for the innovations to be successfully implemented and the benefits to be derived from them (Abubakar et al., 2014). In order to foster BIM adoption, identifying its benefits in construction projects is necessary. Therefore, various BIM implementation benefits in construction projects have been identified and classified by numerous researchers from various countries. Table 1 provides the most significant benefits of BIM adoption in construction projects from prior studies.

Table 1. Summary on benefits of BIM adoption from prior studies

Country	Study	Total benefits identified	Benefits of BIM adoption
Australia	(Hong et al., 2019)	7	(1) cost saving; (2) time saving; (3) improved team work; (4) improved data management; (5) improved understanding of project.
	(Newton and Chileshe, 2012a)	9	(1) improved constructability; (2) improved visualization; (3) improved productivity; (4) reduced clashes; (5) improved quality and accuracy.
Malaysia	(Enegbuma and Ali, 2011b)	7	(1) faster and more effective processes; (2) better design; (3) controlled whole-life costs and environmental data; (4) better production quality; (5) automated assembly.
	(Mohd Noor et al., 2018)	12	(1) more realistic start and finish dates of project activities; (2) rapid consideration of many alternatives schedule; (3) helps managing the schedule changes when and as they occur; (4) helps evaluating overall project performance; (5) helps to ensure that the quality-related activities are being performed effectively.
	(Ibrahim et al., 2019)	56	(1) concepts become clearer and project conceptualization easier; (2) earlier and more accurate visualizations of a design to the owner; (3) support decision making regarding the design; (4) improve feasibility studies; (5) improve simulations and coordination
	(Memon et al., 2014)	8	(1) improved scheduling; (2) improved drawing coordinates; (3) improved work quality; (4) single detailed model; (5) control time and cost.
	(Al-Ashmori et al., 2020)	7	(1) increase productivity and efficiency; (2) assess time and cost associated with design change; (3) eliminate clashes in design; (4) improve multi-party communication and maintain synchronized communication; (5) integrate construction scheduling & planning.
Indonesia	(Sholeh et al., 2020)	6	(1) BIM makes flexibility in design and construction; (2) BIM facilitates supply chain integration between stakeholders; (3) BIM facilitates supply chain integration between project phases; (4) flexible work; (5) better risk-sharing between stakeholders.
Korea	(Ashcraft, 2008)	12	(1) single data entry, multiple uses; (2) design efficiency; (3) consistent design bases; (4) 3D modeling and conflict resolution; (5) conflict identification and resolution.
Hong Kong	(Chan et al., 2019b)	12	(1) better cost estimates and control; (2) a better understanding of design; (3) reduce construction cost; (4) better construction planning and monitoring; (5) improve project quality.
	(Tse et al., 2005)	5	(1) creating views and schedules dynamically and automatically; (2) reflecting changes instantly in all drawings and schedules; (3) single project file; (4) toolbars oriented; (5) compatibility with data exchange standards.
Jordan	(Matarneh and Hamed, 2017)	13	(1) reduce rework during construction; (2) maximizing productivity; (3) reduce conflict/changes; (4) clash detection; (5) enhance collaboration & communication.
Nigeria	(Saka et al., 2019)	15	(1) facilities management; (2) health and safety; (3) energy management; (4) time saving; (5) better coordination.
Vietnam	(Hoang et al., 2020)	14	(1) collaboration improvement; (2) more accurate information from a data-rich asset; (3) automatically updated model; (4) improved interoperability; (5) increased employees' productivity and efficiency.
New Zealand	(Diaz, 2016)	6	(1) better performance and quality of the project; (2) improved productivity; (3) reduction of wastages; (4) faster delivery; (5) new opportunities for revenue and business.
	(Stanley and Thurnell, 2014)	8	(1) the visualization of projects is increased; (2) collaboration on projects is enhanced; (3) the quality level of the finished projects is improved; (4) project conceptualization is made easier; (5) increased ability to print out design details from 5D software enables greater analysis capability.
Singapore	(Qian, 2012)	60	(1) improved forecasting; (2) less project risks; (3) better company image; (4) less mistakes and errors; (5) better project control.

Country	Study	Total benefits identified	Benefits of BIM adoption
Pakistan	(Mostafa et al., 2020)	6	(1) early identification of long completion time; (2) shortening the procurement schedule; (3) exploring design constraints for fabricators; (4) reduce differences between design and manufacturing models; (5) reduce the fabrication cycle time.
	(Masood et al., 2014)	7	(1) reduced construction cost; (2) reduced construction time; (3) improve quality; (4) reduced human resources; (5) reduce contingencies.
UK	(Bryde et al., 2013)	9	(1) cost reduction or control; (2) time reduction or control; (3) communication improvement; (4) coordination improvement; (5) quality increase or control.
Turkey	(Seyis, 2019)	41	(1) planning the tasks and responsibilities in a timely manner; (2) promoting collaboration and coordination in early design phase; (3) automatic implementation of design changes into 3D CAD model; (4) decreasing uncertainties in the processes by clarifying risks; (5) reducing time variances in the processes.
India	(Diaz, 2016)	10	(1) enhancing the project performance; (2) efficient planning and scheduling; (3) detailing the project stages; (4) generating multiple planned scenarios; (5) being used for project bidding purposes.

Underlying rationale

BIM has been acknowledged as one of the most appropriate platforms for the AEC industry, which is considered to be multi-organizational and multi-disciplinary, helping resolve construction performance challenges during the planning, designing, construction, operation, and maintenance stages of the entire project life cycle (Li et al., 2017). In the literature review, relevant studies were explored to identify BIM adoption and implementation in construction projects. Although many studies discussed BIM benefits, there is a gap in the literature regarding specific benefits for project stakeholders. Besides, although the developed countries are harvesting the fruits of the benefits of adopting BIM for the construction industry, the adoption and implementation of BIM for construction projects in Vietnam are very much limited. Therefore, the goal of this study was to determine and evaluate the benefits of BIM adoption for each project stakeholder. To achieve the goal, two main objectives were set:

- To identify the most significant benefits of BIM adoption for project stakeholders.
- To evaluate the most significant benefits of BIM adoption for project stakeholders.

The results of this study are expected to be useful for policymakers, governments, construction enterprises, and other stakeholders in their quest to boost the current uptake of BIM in various construction projects not only in Vietnam but also in other countries with the same socio-economic or cultural circumstances.

The literature review was conducted by collecting and studying relevant research papers considering the various benefits of BIM adoption in the construction industry. These papers reported the top significant BIM benefits. In the course of the study, we revised all benefits by eliminating the replicates, refining the statements, and sharing the updated list with professionals in the construction industry to evaluate the presented benefits and finalize the list. Thus, a long list of benefits was shortened to include the 30 substantial benefits of BIM adoption in construction projects for four main project stakeholders: owners, designers, facility managers, and contractors. The benefits of BIM adoption in construction projects and their related sources are shown in Table 2.

Methodology

1.1. Questionnaire survey and respondents

The literature review was carried out to articulate issues regarding the benefits of BIM adoption and implementation in the construction industry with a particular emphasis on the Vietnamese construction sector. The review also aimed at identifying the potential BIM benefits in construction projects. As a result, a total of 30 significant benefits of BIM adoption for construction project stakeholders were identified in the study. These BIM benefits were tabulated in the form of a questionnaire. The questionnaire was composed of two main parts. The first part contained demographics of the respondents and project characteristics. Its main purpose was to describe the respondents in order to effectively ensure reliability and strengthen research findings. The second part included the list of the identified benefits.

Respondents were selected for the survey based on their previous participation in or direct implementation of construction projects adopting BIM tools in Vietnam. Based on their experience, they evaluated the degree of BIM adoption benefits importance in construction projects following a 5-point Likert scale (i.e.,1 — not important, 2 — somewhat important, 3 — neutral, 4 — important, 5 — very important).

Table 2. Benefits of BIM for construction project stakeholders

Code	Benefits of BIM adoption	References
OB	***Benefits for Owners***	
OB1	Easier to choose investment options	(Eastman et al., 2011; Mesároš and Mandičák, 2017)
OB2	Improve operation and construction management	(Ashcraft, 2008; Hoang et al., 2020; Olawumi and Chan, 2019a; Seyis, 2019)
OB3	Early design assessment to ensure project requirements are met	(Azhar, 2011; Mesároš & Mandičák, 2017)
OB4	Maximize project performance	(Bryde et al., 2013; Diaz, 2016; Enegbuma and Ali, 2011; Olawumi and Chan, 2019a)
OB5	Better marketing of project by making effective use of 3D renderings and walk-through animations	(Azhar, 2011; Eastman et al., 2011)
OB6	Low financial risk because of reliable cost estimates and reduced number of change orders	(Azhar, 2011; Eastman et al., 2011)
DB	***Benefits for Designers***	
DB1	Improve efficiency of design options	(Ashcraft, 2008; Enegbuma and Ali, 2011; Hong et al., 2019; Ibrahim et al., 2019; Olawumi and Chan, 2019; Saka et al., 2019; Seyis, 2019)
DB2	Improve the quality of design drawings	(Ibrahim et al., 2019; Memon et al., 2014; Olawumi and Chan, 2019; Saka et al., 2019)
DB3	Easy conflict detection	(Diaz, 2016; Ibrahim et al., 2019; Matarneh and Hamed, 2017; Saka et al., 2019; Stanley and Thurnell, 2014)
DB4	Minimize conflicts/changes	(Al-Ashmori et al., 2020; Ashcraft, 2008; Hong et al., 2019; Ibrahim et al., 2019; Matarneh and Hamed, 2017; Newton and Chileshe, 2012b; Olawumi and Chan, 2019)
DB5	Easy to adjust design changes	(Al-Ashmori et al., 2020; Ibrahim et al., 2019; Seyis, 2019; Sholeh et al., 2020)
DB6	Easy quantity take-off and cost estimation	(Bryde et al., 2013; Chan et al., 2019b; Hong Duyen et al., 2018; Newton and Chileshe, 2012b; Seyis, 2019)
DB7	Reduce design time and costs	(Ibrahim et al., 2019; Seyis, 2019; Stanley and Thurnell, 2014)
DB8	Easy energy efficiency evaluation of options	(Ashcraft, 2008; Hoang et al., 2020; Olawumi and Chan, 2019; Saka et al., 2019; Seyis, 2019)
DB9	Cooperation and commitment of professional bodies	(Chan et al., 2019b; Ibrahim et al., 2019; Qian, 2012)
DB10	Easy product transfer	(Azhar, 2011; Mesároš and Mandičák, 2017; Qian, 2012)
FB	***Benefits for Facility Managers***	
FB1	Easy planning and resource mobilization	(Al-Ashmori et al., 2020; Chan et al., 2019a; Diaz, 2016; Ibrahim et al., 2019; Olawumi and Chan, 2019; Seyis, 2019)
FB2	Project management and execution improvement	(Azhar, 2011; Eastman et al., 2011)
FB3	Easier to coordinate contractors and stakeholders	(Chan et al., 2019b; Eastman et al., 2011)
FB4	Easier to track and supervise design, construction, and operation	(Al-Ashmori et al., 2020; Ibrahim et al., 2019)
FB5	Predicting potential hazards and solving them	(Ibrahim et al., 2019; Stanley and Thurnell, 2014)

Code	Benefits of BIM adoption	References
FB6	Convenient for managing project data	(Enegbuma and Ali, 2011; Hong et al., 2019; Ibrahim et al., 2019; Olawumi and Chan, 2019; Qian, 2012; Saka et al., 2019; Seyis, 2019)
FB7	Better management and operation of facilities	(Azhar, 2011; Eastman et al., 2011; Meadati et al., 2010)
FB8	Operational simulation for maintainability	(Azhar, 2011; Eastman et al., 2011; Meadati et al., 2010; Mesároš and Mandičák, 2017)
CB	***Benefits for Contractors***	
CB1	Easy clash detection	(Diaz, 2016; Ibrahim et al., 2019; Matarneh and Hamed, 2017; A. Saka et al., 2019; Stanley & Thurnell, 2014)
CB2	Minimize construction errors	(Ashcraft, 2008; Ibrahim et al., 2019; Mostafa et al., 2020; Qian, 2012; Saka et al., 2019; Seyis, 2019)
CB3	Convenient for handing over works	(Azhar, 2011)
CB4	Convenient for planning and resource provisioning	(Al-Ashmori et al., 2020; Chan et al., 2019a; Diaz, 2016; Ibrahim et al., 2019; Olawumi and Chan, 2019; Seyis, 2019)
CB5	Construction time saving	(Bryde et al., 2013; Chan et al., 2019a; Hong et al., 2019; Ibrahim et al., 2019; Masood et al., 2014; Mostafa et al., 2020; Qian, 2012; Saka et al., 2019; Seyis, 2019)
CB6	Construction cost saving	(Ashcraft, 2008; Bryde et al., 2013; Chan et al., 2019a; Diaz, 2016; Hoang et al., 2020; Hong et al., 2019; Ibrahim et al., 2019; Masood et al., 2014; Olawumi and Chan, 2019; Qian, 2012; Saka et al., 2019)

Out of 250 questionnaires distributed among construction practitioners, only 168 were filled in. Answers with incomplete data or missing values were removed. Finally, 159 valid questionnaires were collected (age average — 32.5, SD = 4.528), this represented an approximately 63.6% usable response rate.

1.2. Survey results

Among 159 valid answers, 78.62% respondents were male and 21.37% were female. Most of the them — 151 respondents (94.97%) — had bachelor's degrees. Only seven respondents (4.40%) had master's degrees, and only one respondent had a PhD (0.63%). This is relevant to the years of their experience in the construction industry. More than a half — 93 respondents (58.49%) — had 1–5 years of experience. Other groups had experience of 6–10 (22.01%), 11–15 (10.06%), and 16–20 years (2.52%). Besides, 11 respondents (6.92%) had more than 20 years of experience.

In terms of organizations involved in construction projects, the majority — 81 respondents — worked at contractor companies, accounting for 50.84% of the total. Those organizations were followed by design enterprises, with 66 respondents (41.51%), and 12 owners (7.55%). In terms of job position, the majority were designers (64 respondents, accounting for 40.25% of the total). The share of project managers/facility managers was 22.01% (35 respondents); while estimators (35 respondents) and site engineers (24 respondents) accounted for 22.01% and 15.09%, respectively.

In terms of construction characteristics, most of the projects were related to building (106 projects, 66.67%), followed by industrial ones (28 projects, 17.61%). Infrastructure projects accounted for 10.06% (16 projects) while the figure for transportation was only 5.66% (9 projects). Among these projects, 90 (56.60%) were private-financed, 57 (31.45%) were public-financed, and the rest 12 projects (7.55%) were financed using offshore funds. More than a half of the projects (102 projects, 64.15%) were medium to big scale (≥ 15 VND billions), and 50 projects (31.45%) were small scale (≤ 15 VND billions), while only 7 projects (4.40%) were nationally important.

Data analysis

1. Internal consistency of the questionnaire

Cronbach's alpha is a measure the reliability of internal consistency that assumes the same thresholds but yields lower values than the composite reliability. We aimed to determine Cronbach's alpha so as to confirm that the criteria associated with the Likert's scale measure each variable that was intended to be measured (which is the importance of each benefit of BIM adoption in construction projects for stakeholders). The study of (Vaske et al., 2017) explained that Cronbach's alpha measures the extent to which answers to survey questions correlate with each other, which means α estimates the proportion of variance that is systematic or consistent in a set of survey responses. The standard for evaluating the level of relevance of the model is a value where Cronbach's alpha is higher than 0.7. Then questionnaires are generally accepted as accurate (Fang et al., 2004; Hai et al., 2022; Hair et al., 1998). The 'Cronbach's Alpha if item deleted' option makes it possible to examine whether the removal of any items would enhance the reliability of a specific variable scale that showed an unsatisfactory Cronbach's alpha value (i.e., the score less than 0.3). Cronbach's alpha coefficient can be determined by Eq. (1) as follows:

$$Cronbach\text{'}s\ alpha\ \alpha = \frac{N.C}{v+\left(N-1\right).C}, \quad (1)$$

where N represents the number of item indicators; C the coefficient of correlation of the average non-redundant indicator (i.e., the mean of the lower or upper triangular matrix); and v is the average variance.

Table 3. Results of Cronbach's alpha test of internal consistency

Code	Cronbach's Alpha if Item Deleted	Cronbach's Alpha
OB1	0.895	0.913
OB2	0.886	
OB3	0.880	
OB4	0.896	
OB5	0.928	
OB6	0.898	
DB1	0.939	0.947
DB2	0.940	
DB3	0.940	
DB4	0.941	
DB5	0.941	
DB6	0.942	
DB7	0.940	
DB8	0.942	
DB9	0.943	
DB10	0.941	
FB1	0.945	0.948
FB2	0.938	
FB3	0.940	
FB4	0.939	
FB5	0.941	
FB6	0.939	
FB7	0.940	
FB8	0.946	
CB1	0.899	0.904
CB2	0.880	
CB3	0.898	
CB4	0.880	
CB5	0.885	
CB6	0.878	

As demonstrated in Table 3, the results of Cronbach's alpha for the components are 0.913, 0.947, 0.948, and 0.904, respectively. These values are higher than 0.7, thereby reliability is acceptable. The observed variables have Cronbach's alpha if item is deleted > 0.3, thus they are closely related to other variables; these variables are all measuring the same construct and therefore there will be no basis for removing any item.

2. Kaiser–Meyer–Olkin test and Bartlett's test of sphericity

The Kaiser–Meyer–Olkin Measure of Sampling

Adequacy and Bartlett's Test of Sphericity were adopted to assess if exploratory factor analysis is reasonable. Bartlett's test for testing the null hypothesis assumed that the extracted principal components or factors did not make unique contributions to the outcome being investigated or are significantly correlated with each other. The following is recommended: 0.5 ≤ KMO ≤ and Sig < 0.05 (Bryman and Cramer, 2011; Hair et al., 1998). As shown in Table 4, the result of the KMO test indicated a coefficient value of 0.937 > 0.5, which is a strong measure of sampling adequacy. This demonstrated that the partial correlations or multicollinearity structures between the factors were sufficient to justify aggregating the variables into related sets for extraction of the principal components. Bartlett's Test of Sphericity with Sig = 0.00 < 0.05 proves that the observed variables have an overall correlation with each other. Hence, the result reinforced the four principal components' reliability and validity extracted from the 30 observed variables.

Table 4. Results of KMO and Bartlett's tests

Kaiser–Meyer–Olkin Measure of Sampling Adequacy		0.937
Bartlett's Test of Sphericity	Approx. Chi-Square	4952.620
	df	435
	Sig	0.000

3. Factor loadings

Variables with eigenvalue less than 1 do not have better function in summarizing information than original factors. Hence, variables are only extracted if eigenvalue is more than 1 and are accepted if variance extracted is more than 50%. In other words, the software statistically defined a group of factors as highly intercorrelated when the group had eigenvalue of at least 1. The other components, with eigenvalue less than 1, were considered as "scree" and assumed not to represent any real traits underlying the 30 variables. Factor loadings describe how much correlation exists between observed variables and underlying factors. These values should be more than 0.3 (Bryman and Cramer, 2011; Hair et al., 1998).

Table 5. Factor loadings on the four components

Code	**Component**			
	DB	**FB**	**CB**	**OB**
DB2	0.754			
DB4	0.746			
DB1	0.743			
DB7	0.692			
DB10	0.667			
DB3	0.664			
DB9	0.634			
DB6	0.618			
DB5	0.555	0.504		
DB8	0.524			
FB6		0.736		
FB1		0.708		
FB7		0.691		
FB4		0.688		
FB3		0.686		
FB2		0.685		
FB8	0.518	0.565		
FB5		0.516		

Code	Component			
	DB	FB	CB	OB
CB2			0.754	
CB6			0.713	
CB4			0.675	
CB1			0.653	
CB5			0.556	
OB5	0.518		0.547	
CB3				
OB4				0.815
OB1				0.799
OB3				0.741
OB2				0.723
OB6				0.618
Initial eigenvalues	17.686	1.793	1.405	1.121
% of variance	58.954	5.975	4.682	3.736
Cumulative %	58.954	64.929	69.611	73.347

Table 5 provides the results for three extracted components and principal variables loaded on the four components (i.e., DB — Benefits for Designers, FB — Benefits for Facility Managers, CB — Benefits for Contractors, and OB — Benefits for Owners). The four underlying categories of variables accounted for 73.347 % of the total cumulative variance. It is more than 50%, which proves that the variation of the observed variables is considered acceptable. Table 5 shows that all observed variable correlations are more than 0.3, indicating a robust inter-item correlation within each principal component. It also demonstrates a strong representation of the variables by the extracted elements. Exploratory factor analysis was conducted to analyze the relationships among the correlated variables and reduce the data, which helped to confirm the structure of the model. Factors with loading below 0.50 (cut-off for significance) or incidence of cross-loading were found to be weak indicators of the constructs and therefore were not included in the components (Cho et al., 2009; Field, 2013). On that basis, several problematic factors were omitted from all items, including DB5 — easy to adjust design changes, CB3 — convenient for handing over works, FB8 — operational simulation for maintainability, and OB5 — reduce time solving conflicts.

Discussion

This section will discuss the benefits of BIM implementation in construction projects for stakeholders based on data analysis results. The analysis is divided into four primary parts as follows: benefits of BIM adoption for architectural and structural design units, benefits of BIM adoption for facility management units, benefits of BIM adoption for contractors, and benefits of BIM adoption for project owners, which are discussed in this section.

1. Benefits of BIM adoption for architectural and structural design units

As demonstrated in Table 5, 10 variables loaded strongly and positively on the DB component, of which there was only one item cross-loading on another component, accounting for 33.3% of the total number of variables. This component explains 58.954% of the total variance among 30 variables. This means that analysis of the underlying benefits of BIM adoption in the order of their relative loading coefficients could confirm the valuable BIM implementation in construction projects. The most prominent benefit within the cluster of benefits for architectural and structural design units is ‘improve the quality of design drawings’. This finding was further supported by studies of (Al-Ashmori et al., 2020; Ashcraft, 2008; Chan et al., 2019b; Enegbuma and Ali, 2011; Ibrahim et al., 2019; Mostafa et al., 2020), which revealed that one of the primary advantages of BIM adoption was improved drawing quality. This may be because building proposals can be rigorously analyzed, simulations performed quickly, and performance benchmarked, enabling improved and innovative solutions; documentation output is flexible and exploits automation (Azhar, 2011).

The surveyed respondents evaluated ‘minimize conflicts/changes’ as the second influential benefit for designers. This result is in the line with the findings of several previous studies (Diaz, 2016; Ibrahim et al., 2019; Matarneh and Hamed, 2017;

Saka et al., 2019; Stanley and Thurnell, 2014), which demonstrated that BIM is capable of detecting potential conflicts and minimizing drawing changes during the design phase. Clash avoidance is a key part of the design and construction process. During the design process, every BIM module or user shall assess design decisions and clashes to see if there is any problem early in the design stage (Ibrahim et al., 2019). Detecting clashes and minimizing conflicts and changes during construction are two of the top ways engineers say BIM adds value to a project (Matarneh and Hamed, 2017).

Implementing BIM in construction projects also brings several benefits for architectural and structural design units such as ‘improve efficiency of design options’, ‘reduce design time and costs’, ‘easy product transfer’, ‘cooperation and commitment of professional bodies’, and ‘easy quantity take-off and cost estimation’. In fact, with an appropriate price database, the construction costs will be significantly saved. This utility is especially meaningful in the design phase of a project when the designs often change, and the investor urgently needs information to choose the option in time (Ashcraft, 2008; Chan et al., 2019b; Saka et al., 2019; Seyis, 2019; Stanley and Thurnell, 2014). The study of (Ashcraft, 2008) indicated that the model contains necessary information on quantity and estimated cost, avoiding processing of material take-offs manually, thus reducing error and misunderstanding.

The early design and pre-construction phases are the most important stages in deciding on the sustainability characteristics of a building (Azhar et al., 2009). In the early stages of design development, traditional Computer-Aided Design (CAD) planning environments usually lack the capacity to conduct sustainability analyses. Usually, construction performance evaluations are carried out after the architectural design and construction documents have been created. This failure to consistently evaluate sustainability during the design process results in inefficient retroactive design adjustment to meet a set of performance criteria (Schlueter and Thesseling, 2009). Access to a comprehensive collection of data regarding the shape, materials, context, and systems of a building is needed to realistically evaluate building performance in the early design and pre-construction phases. Since BIM enables multi-disciplinary data to be superimposed within a single model, it provides an opportunity to integrate sustainability measures into the design process (Autodesk, 2008). Azhar (Azhar, 2011) found that by conducting BIM-based sustainability analyses, data for up to 17 LEED® (Leadership in Energy and Environmental Design, a green building ranking system used in the USA) credits can be obtained in the design process. This implies that a building knowledge model can be used for LEED® research as a by-product, thereby saving considerable time and energy.

2. Benefits of BIM adoption for facility management units

As shown in Table 5, the FB component received the second-highest factor loading with 8 of the 30 variables, accounting for 26.7% of the items. This reveals that BIM adoption in construction projects can bring eight primary benefits for facility management units. This component accounts for 5.975% of the variance among the 30 items. The most prominent benefit within this cluster is ‘convenient for managing project data’. “With the BIM database, any information about an equipment is just one click away”, as Reddy (2011) stated. In the past, buildings would be turned over to facility managers with boxes and piles of manuals and warranties from the owner. In order to obtain data on product details, warranties, product life cycle, maintenance controls, replacement costs, installation and repair procedures, and even place an order for a replacement online, facility managers can now click on any equipment or fixture (Jordani, 2010). Developments in mobile phones and tablets (such as iPhone® and iPad®) and Virtual Reality (AR) have made it possible to gain full information about a building by simply pointing the device to it. An AR-based program, InfoSPOT®, developed at the Georgia Institute of Technology, Atlanta, Georgia, was reported by Joyce (2012), which enables facility managers to quickly obtain “on the spot” information about equipment using their smartphones.

The second prominent benefit for facility management units is ‘easy planning and resource mobilization’. This is because BIM provides project management with a visual model and integrated elements such as construction progress, labor chart, and construction cost development chart, helping managers with easy tracking and supervision. Moreover, monitoring and tracking progress during the project life cycle significantly influenced the practitioners’ decision to enhance mutual trust, respect, and personal commitments to cooperation (Al-Ashmori et al., 2020). Besides, implementing BIM in construction projects can bring other benefits for the facility management, such as ‘project management and execution improvement’, ‘easier to coordinate contractors and stakeholders’, ‘easier to track and supervise design, construction, and operation’, ‘predicting potential hazards and solving them’, ‘better management and operation of facilities’, and ‘operational simulation for maintainability’. The challenge of managing a project is to ensure project success, and the key to achieve it is risk management at the earliest stages before it becomes costlier (Abdullah et al., 2015). Facility management departments can use BIM for renovations, space planning, and maintenance operations (Azhar, 2011). Thanks to BIM models, potential hazards are not only anticipated at the early stage, but they are also solved automatically by the software.

3. Benefits of BIM adoption for contractors

The constructor is the third principal component receiving benefits of BIM implementation in construction projects. This cluster includes six variables (20.00% of the total) and explains 14.682% of the total variance among 30 variables. Contractors and subcontractors can use BIM for many tasks such as quantity take-off and cost estimation (Duyen et al., 2018); early identification of design errors through clash detections; construction planning and constructability analysis; onsite verification, guidance, and tracking of construction activities; offsite prefabrication and modularization; site safety planning; value engineering and implementation of lean construction concepts; and communication with the project owner, designer, subcontractors and workers on site (Hardin and McCool, 2015; Nguyen et al., 2021; Nguyen Van et al., 2021; Van Tam et al., 2018). According to the analysis results, ‘minimize construction errors’ and ‘construction cost saving’ are the most prominent benefits for contractors when adopting BIM in construction projects. These findings were supported by (Ibrahim et al., 2019) who explained that construction errors, besides causing cost-related waste, strongly affects the project’s sustainability. Implementation of BIM in the construction phase will be able to reduce error, rework and waste for better sustainability for construction since it is connected to the database.

Implementing BIM in construction projects also can bring several other benefits for constructors, such as ‘easy clash detection’, ‘convenient for handing over work’, ‘convenient for planning and resource provisioning’, and ‘construction time saving’. The study of (Azhar et al., 2012) presented a case study illustrating the use of BIM by the general contractor (GC) to minimize design errors via clash detections. The project was a $35 million academic building at the campus of Emory University, Atlanta, Georgia, USA. The architect of the project designed the architectural model. The GC received drawings of 2D structural and MEP structures from project engineers and turned them into 3D BIM models. The GC was able to save approximately $259,000 by combining all ‘single’ BIM models and through clash detections in the pre-construction phase.

4. Benefits of BIM adoption for project owners

As provided in Table 5, only 5 variables were loaded in this cluster, accounting for 16.67% of the total; explaining 3.736 % of the total variance among 30 variables. In projects where BIM technologies and processes are implemented, owners can gain considerable benefits (Eastman et al., 2011; Reddy, 2011). The most prominent benefit for project owners is ‘maximize project performance’. This result is in line with some previous studies such as (Chan et al., 2019b; Diaz, 2016; Mohd Noor et al., 2018; Olawumi and Chan, 2019; Seyis, 2019), which affirmed that the main advantage of BIM is an increase in building performance and quality. Project performance was also considered as an item giving most benefits towards the project quality (Mohd Noor et al., 2018). The surveyed respondents evaluated ‘easier to choose investment options’ as the second prominent benefit for project owners. Besides, several other benefits of BIM adoption in this cluster include ‘improve operation and construction management’, ‘early design assessment to ensure project requirements are met’, ‘better marketing of project by making effective use of 3D renderings and walk-through animations’, and ‘low financial risk because of reliable cost estimates and reduced number of change orders’. In fact, 3D renderings can be easily generated in a house with little additional effort (Azhar, 2011). The study of (Chan et al., 2019b) indicated that BIM implementation improves project quality variables by facilitating the ease of assessment of construction materials and work processes. An organization’s policy or strategy toward integrating and implementing BIM in their work processes aims to reduce financial risk and improve their competitive advantages.

Conclusions, contributions, and limitations

BIM represents a new paradigm within the architecture, engineering, and construction (AEC) industry, one that encourages integration of the roles of all stakeholders on a project. Implementing BIM in the construction industry can bring valuable benefits for project stakeholders. The survey showed that construction practitioners belong to four primary clusters of project stakeholders receiving benefits of BIM adoption in construction projects: architectural and structural design units (10 benefits), facility management units (8 benefits), contractors (6 benefits), and owners (6 benefits). The reliability and validity of the research design and findings were evaluated via prescribed quality assurance tests, including Cronbach’s alpha test of internal consistency, KMO measure of sampling adequacy, Bartlett’s test of sphericity, and factor loadings. The analysis of the test results confirmed the reliability and validity of the research design and findings.

According to the findings, ‘improve the quality of design drawings’ and ‘minimize conflicts/changes’ are the most significant BIM benefits for architectural and structural design units. Meanwhile, ‘convenient for managing project data’ and ‘easy planning and resource mobilization’ are benefits that facility management units gained most from BIM. As for contractors, ‘minimize construction errors’ and ‘construction cost saving’ were the most prominent BIM benefits. For owners, BIM’s two most striking benefits are ‘maximize project performance’ and ‘easier to choose investment options’.

The main contribution of this study to the existing body of knowledge is the investigation of the benefits of BIM implementation and adoption for project stakeholders. In the context of the Vietnamese construction industry, this study contributes to filling a crucial knowledge gap by providing information on various manageable BIM benefits to boost BIM in construction projects and attain high performance in a typical developing economy setting.

The main limitation of this study is that it was conducted only in the Vietnamese construction industry context. It seems rather modest compared to many countries and construction projects applying BIM technology around the world. This was a snapshot view of BIM adoption benefits for stakeholders aimed to foster BIM implementation in the Vietnamese construction industry; hence, the findings are not future proof. Rapid changes driven by advanced technology would necessitate these benefits to be re-investigated and up to date with new and emerging critical benefits. In addition, this study does not provide quantitative parameters to help the readers understand the extent of the benefits (e.g., cost-saving, time saving) for project stakeholders in a specific project case. Therefore, further studies should consider the benefits of BIM implementation in construction projects at different levels such as industry level, enterprise level, project level, or activity level.

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