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Article

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Factors affecting adoption of building information modeling in construction projects: A case of Vietnam

Nguyen Van Tam¹, Tran Ngoc Diep¹, Nguyen Quoc Toan¹ and Nguyen Le Dinh Quy^{2*}

Abstract: BIM exhibits strong potential to become a core technological advancement adopted in construction projects. However, the process of BIM implementation is being affected by various factors depending on specific circumstances. This study aims to identify global factors influencing BIM adoption in construction projects. By a comprehensive review of the previous literature, this study managed 39 critical factors impacting construction labor productivity, which were categorized as primary 5 groups, namely, human, management, technology, project, and external. A total of 159 valid samples were collected by respondents who completed a questionnaire survey according to their previous direct or indirect participation in the implementation of construction projects. These factors were ranked based on their Relative Important Index (RII) and descriptive statistics. The findings indicated that the most significant factors affecting BIM adoption in construction project implementation consist of (1) “perceived usefulness,” (2) “speed of BIM tools,” (3) “perceived benefits of BIM for organization,” (4) “technology quality,” and (5) “experience and skills”.



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PUBLIC INTEREST STATEMENT

Building Information Modeling (BIM) has provided a method for increasing total project quality, providing accurate quantity take-offs, and improving scheduling, resulting in lower total project contingencies and costs. This study identified and assessed a total of 39 factors impacting BIM adoption within the construction project implementation. These factors are grouped into five main categories, namely, human, management, technology, project, and external. The findings provide a comprehensive understanding of factors affecting BIM adoption in construction projects. This enables the government, managers, and practitioners to make reasonable policies to foster BIM adoption in construction industry.

Subjects: Building and Construction; Building Project Management; Project Management

Keywords: BIM adoption; factors; affecting; construction projects

1. Introduction

Building Information Modeling (BIM) is a repository of digital information that increases the effectiveness and efficiency of construction project management (Latiffi et al., 2013; Olawumi & Chan, 2019). The paradigm shift in the construction process is experiencing an increased transfer of technological advancement from developed countries to developing countries, which makes a deep and fundamental change that is rapidly transforming the global construction sector (Abubakar et al., 2014; Enegbuna & Ali, 2011). The BIM adoption and implementation in the construction project foster sustainable construction and contribute to eradicating poverty in developing nations (Bui et al., 2016). In Vietnam, the construction industry has made significant progress towards modernization and globalization in recent decades, which saw the strong development of many fields, such as construction technologies, construction project management, construction materials, architectures and construction planning, urban and housing development. Although Vietnamese labor productivity has recently been improved, it is still lower than in other countries in Southeast Asia (Hai & Van Tam, 2019; Van Tam et al., 2018, 2021). Hence, the adoption of BIM in construction project implementation is an effective measure to improve construction productivity and enhance construction project performance. BIM has been adopted in the Vietnam construction sector since early 2000, but it is still not spread widely. This is particularly the case in construction projects funded with state-owners capital, which accounts for the largest market share of construction projects in Vietnam (Dao & Chen, 2020a). Awareness about the benefits of BIM adoption and implementation, Vietnam has set 2021 as the target year for adopting BIM for all governmental and large construction projects (Dao & Chen, 2020b). Perceiving the trends of BIM technologies adoption, investors and construction enterprises has also initially realized the benefits of adopting BIM. Numerous design companies and contractors have gradually put the adoption of BIM tools into practical projects from the concept design stage to construction management stage. Investors play a very important role in the process of promoting BIM application in Vietnam. However, the number of large investors who are aware of these benefits is still modest. Some of them are VinGroup, Bitexco, Vietinbank being one of the few investors who intend to apply BIM to control each part of the project from the design stage to the handover and operation stage. Design consulting enterprises are the first to start BIM adoption in Vietnamese construction industry. Several companies are applying BIM tools for architectural designs such as VNCC, CDC, PTW, and Hacid enterprises. Particularly, VNCC and Constrexim ICC as the typical examples, with 100% of projects applying Revit Architecture for architectural design. Some contractors have started to adopt BIM to construction projects during the bidding phase to dissect the work volume and formulate measures to organize construction based on BIM models. In addition, the contractors have initially applied models to control clashes between structures and between departments in the construction phase and to exchange information between project stakeholders. Several typical contractors for the adoption and implementation of BIM in the construction process that are Hoa Binh Construction and Real Estate Joint Stock Company, Cotec Construction Joint Stock Company, Construction Joint Stock Company No.1. Besides domestic private enterprises, foreign contractors in Vietnam have also initially deployed BIM applications in projects, such as Posco E&C, Taisei, Maeda, Lotte E&C. Among them, Lotte has become a typical contractor in using BIM software to design beam structure systems and control the concrete construction volume of the entire Hanoi Lotte Center project. Some construction projects applied BIM in Vietnam, such as Diamond Island Sky Resort; Delta River Tower; Technology Park City University of Technology. Ho Chi Minh City—branch in Binh Duong; Tri Viet eco-park resort, Hoi An; Vietinbank Tower; Metro line 2: Ben Thanh—Tham Luong; National Highway 1 passes through Quang Tri; Saigon Bridge 2; Tunnel across the Saigon River.

BIM is being a new technology in Vietnam construction industry, which is expected to deliver numerous benefits to the industry, such as project performance and quality enhancement (Succar, 2009); initial conflict control in the designing (Azhar, 2011), effective construction process (Abd Hamid et al., 2018), enhance collaboration among construction stakeholders (Kerosuo et al., 2015; Succar, 2009); 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 & Moud, 2013). Prior studies indicated that BIM adoption is affected by various factors related to users, technology, management, project characteristics, tools, and environment (Abubakar et al., 2014; Chan, Olawumi, Ho et al., 2019a; Ezeokoli et al., 2016; Noor et al., 2018). For many years, the topic of factors influencing BIM adoption in the construction sector has been a concern of numerous researchers. Consequently, various factors that impact the adoption and implementation of BIM have been identified and classified by many studies from different countries. However, the frequency and importance of these factors vary from project to project or nation to nation, and even within the same project, depending on circumstances. Hence, this study aims to identify and assess the factors impacting BIM adoption within construction project implementation through data collected in an investigation in Vietnam.

2. Literature review

BIM is one of the critical innovations that represent a technological and procedural shift in the construction industry. BIM represents a methodology to manage the building design and project data in digital format throughout the building lifecycle (Panuwatwanich & Peansupap, 2013). The introduction and adoption of any new technological advancement like BIM usually require that the factors that may affect the adoption by the project stakeholders be identified and addressed for the successful take-up of the innovations and subsequent benefits to be derived thereof (Abubakar et al., 2014). In order to foster BIM adoption, identifying factors affecting BIM adoption in construction projects is necessary. Therefore, various factors influencing labor productivity in the construction industry have been identified and classified by numerous researchers from different countries as provided in Table 1.

Based on referencing and considering previous studies, this study synthesized some of the most important factors impacting BIM adoption in construction projects. As provided in Table 2, a total of 39 factors influencing BIM adoption in construction projects, which are divided into five categories as follows: (1) human (7 factors), management (11 factors), technology (10 factors), project (5 factors), external (7 factors).

3. Research methodology

A comprehensive literature review was conducted to articulate issues regarding BIM adoption in the Vietnam construction industry and identify the factors affecting BIM adoption in construction projects. As mentioned above, a total of 39 factors that affect BIM adoption in the construction project implementation were identified. These factors were then tabulated in the form of a questionnaire.

3.1. Sampling and data collection

Data were collected from respondents who completed a structured questionnaire survey according to their previous direct or indirect participation in the implementation of construction projects adopting BIM tools. A total of 250 questionnaires were distributed both by way of an interview (180) and utilizing an online survey platform (70). The authors conducted the interview are BIM users working in small, medium, and large construction enterprises in Vietnam. As for the online method, the questionnaires were sent to preselected people who had been ensured to at least have first-hand knowledge of BIM. Any questionnaires that included incomplete data or missing values were removed. Finally, 159 valid questionnaires were collected (age average is 32.5, SD = 4.528), in which, valid questionnaires received from the former method were 107 (67%) and from the online survey were 52 (33%). The valid response rate for interviews was 61% while

Table 1. Summary of previous studies on factors affecting BIM adoption in construction projects

Country	Study	Total factors identified	Top factors affecting BIM adoption
Malaysia	(Shehzad et al., 2019)	74	(1) Compatibility; (2) lack of training; (3) top management support; (4) normative pressure; (5) self-efficacy; complexity; subject norms
	(Noor et al., 2018)	27	(1) Better visualization compares to traditional CAD technology; (2) the capability of financial resources; (3) Better schedule estimation than traditional CAD technology; (4) The ability of BIM in visualization; (5) Experience in BIM technology
	(Mohammad et al., 2018)	24	(1) People; (2) relative advantage; (3) compatibility; (4) management; (5) training
	(Enegbuma & Ali, 2011)	5	(1) Construction policy; (2) strategic information, communication, and technology; (3) education and training; (4) legal parameters; (5) implementation framework.
Nigeria	(Abubakar et al., 2014)	10	(1) Availability of trained professionals to handle the tools; (2) BIM software availability and affordability; (3) enabling environment; (4) clients' interest in the use of BIM in their projects; (5) awareness of the technology among industry stakeholders
	(Ezeokoli et al., 2016)	8	(1) Compatibility between software platforms; (2) level of knowledge and awareness index; (3) structure/culture of the industry; (4) availability of the appropriate technology and infrastructure; (5) cost of technology and its implementation
Hong Kong	(Chan, Olawumi, Ho et al., 2019b)	11	(1) Client's acceptance with BIM projects; (2) financial support from the government to set up BIM system; (3) organizational structure to support BIM system within company; (4) BIM training programs; (5) information-sharing protocols
UK and USA	(Panuwatwanich & Peansupap, 2013)	5	(1) BIM is required by clients; (2) other project team members decide to move to BIM; (3) adequate technical support and training are provided; (4) observable large productivity gain; (5) downstream applications of BIM are in place.
China	(Wang et al., 2016)	18	(1) Comparative Advantage; (2) Enterprise Scale; (3) IT Ability; (4) Business Situation; (5) Expected Benefits.
	(Qin et al., 2020)	15	(1) Requirement from national policies; (2) popularity of BIM in the industry; (3) standardization of BIM; (4) traditional thinking mode; (5) executive support

(Continued)

Country	Study	Total factors identified	Top factors affecting BIM adoption
India	(Ahuja et al., 2020)	9	(1) Complexity; (2) Compatibility; (3) Perceived costs; (4) Expertise; (5) Client Requirement
Australia	(Hong et al., 2016)	10	(1) Ease of maintenance; (2) organizational support; (3) awareness; (4) perceived usefulness; (5) down time
	(Sargent et al., 2012)	11	(1) Ease of use; (2) Perceived ease of use; (3) Perceived usefulness; (4) Social factors; (5) Facilitating conditions
USA	(Liu et al., 2010)	4	(1) Top management support; (2) perceived benefit; (3) IT sophistication; (4) external force
Vietnam	(Dao & Chen, 2020a)	11	(1) Lack of BIM regulations; (2) No correlation of the systems leading to the difficulty of the authorities to inspect/supervise; (3) Lack of consistency and participation of stakeholders; (4) Lack of contract forms to clearly mandate the BIM practices and address legal concerns (5) Liability exposures to design errors, non-compliant design, transition errors, loss of data or data misuse
Singapore	(Attarzadeh et al., 2015)	45	(1) Initial investment cost for BIM adoption (software and hardware accumulation); (2) efficiency and simplicity of the BIM software; (3) government policies and support for BIM adoption; (4) organization's financial resources; (5) organization's top management support for BIM adoption

77% of the distributed online forms were completed. Table 3 presents the demographics of the respondents under investigation.

3.2. Measurement method

For analyzing data, this study used descriptive statistics (i.e., mean and standard deviation) and Relative Importance Index (RII) approaches to measure the impact of factors affecting BIM adoption in construction projects. The RII index was calculated based on the following equation (Eq. 1) (Alaghbari et al., 2019; Soekiman et al., 2011):

$$RII = \frac{\sum_{i=1}^5 W_i \times X_i}{5 \sum_{i=1}^5 X_i} \quad (1)$$

where W_i is the rating given to each factor by the participant ranging from 1 to 5; X_i represented the percentage of respondents scoring and reflected the order number for the respondents; i is the order score ranging from 1 to 5.

Responses from the first part can be obtained through the appropriate response choice (i.e., demographic of the respondents). In the second part (i.e., list of 39 factors) participants needed to assess the factors that influence BIM adoption in construction projects on a Likert scale from 1 (very low effect) to 5 (very high effect).

Table 2. Factors influencing BIM adoption in construction projects

Category	Factor	Definition	Related sources
Human factors	Perceived usefulness	This refers to the degree to which an individual believes that using BIM technology would enhance his or her job performance	(Shehzad et al., 2019, Qin et al., 2020, Hong et al., 2016, Sargent et al., 2012)
	Perceived ease of use	This refers to the degree to which an individual believes that using BIM technology would be free of effort	(Shehzad et al., 2019, Qin et al., 2020, Sargent et al., 2012)
	Experience and skills	This refers to the knowledge or ability of users in applying BIM technology	(Shehzad et al., 2019, Attarzadeh et al., 2015)
	Personal competency	This refers to users' particular qualities required to possess in order to apply BIM technology	(Shehzad et al., 2019, Attarzadeh et al., 2015)
	Interest	This refers to an individual's attention or wanting to be involved with in using BIM tools	(Shehzad et al., 2019)
	Willingness to use BIM	This refers to the quality of being happy to implement BIM technology if it is necessary	(Chan, Olawumi, Ho et al., 2019b, Attarzadeh et al., 2015)
	Work motivation	This refers to the human drive to work in order to gain rewards from that work	(Shehzad et al., 2019)
Management factors	Organizational readiness	This refers to the relationship between people, processes, systems and performance measurement, making a state of being willing and able to take action in applying BIM technology	(Shehzad et al., 2019, Qin et al., 2020, Hong et al., 2016)
	Perceived benefits of BIM for organization	This refers to the perception of the positive consequences that are caused by applying BIM technology	(Liu et al., 2010, Attarzadeh et al., 2015)
	Organization's policies	This refers to the standards, principles, and procedures given by the organization towards BIM implementation decision	(Shehzad et al., 2019, Mohammad et al., 2018)
	Organization's capacity	This refers to the capability or all components it takes for an organization to adopting BIM technology.	(Shehzad et al., 2019, Attarzadeh et al., 2015)
	Financial resources	This refers to the resources from which an organization obtains the funds it needs to finance the investments, capital and current activities, including costs for BIM application	(Noor et al., 2018, Shehzad et al., 2019, Mohammad et al., 2018, Chan, Olawumi, Ho et al., 2019b, Attarzadeh et al., 2015)
	Availability of BIM users	This refers to the possibility that an organization can reach the employee who can use BIM technology	(Abubakar et al., 2014, Shehzad et al., 2019, Chan, Olawumi, Ho et al., 2019b, Qin et al., 2020, Ahuja et al., 2020, Hong et al., 2016)
	Manager's Support	This refers to the action or the recognition of the manager in order to provide the right conditions for the implementation of BIM technology in the organization	(Noor et al., 2018, Shehzad et al., 2019, Mohammad et al., 2018, Chan, Olawumi, Ho et al., 2019b, Wang et al., 2016, Ahuja et al., 2020, Hong et al., 2016, Sargent et al., 2012, Liu et al., 2010, Attarzadeh et al., 2015)
	Perceived Risks	This refers to the organization's perception of the risks associated with any purchase and is mostly associated with products that are expensive or complex with many features such as BIM technology	(Shehzad et al., 2019, Mohammad et al., 2018, Wang et al., 2016)
	Capacity to use information technology	This refers to the capability of an organization in accomplishing information technology in order to fostering BIM technology	(Noor et al., 2018)
	Organization's culture	This is the set of underlying beliefs, values, principles, and ways of interacting within an organization	(Ezeokoli et al., 2016, Chan, Olawumi, Ho et al., 2019b, Attarzadeh et al., 2015)
	Availability of technical infrastructure	This refers to the possibility that a BIM user can reach the necessary infrastructure for implementing BIM technology in an organization.	(Panuwatwanich & Peansupap, 2013, Chan, Olawumi, Ho et al., 2019b)

(Continued)

Table 2. (Continued)

Category	Factor	Definition	Related sources
Technological factors	Feasibility using BIM	This refers to the potential or possibility that can be made, done, or achieved, or reasonable while applying BIM in construction projects	(Shehzad et al., 2019)
	IT support	This refers to the IT conditions that enable to learn IT technology such as BIM.	(Shehzad et al., 2019, Wang et al., 2016)
	Triability	This refers to the experimental practice of new technology (BIM) in a limited range	(Wang et al., 2016, Ahuja et al., 2020)
	Accessibility	This refers to the degree to which a product, device, service, or environment are available to as many people as possible	(Shehzad et al., 2019)
	BIM complexity	This refers to the characteristics of BIM technology including many parts and being difficult to understand	(Wang et al., 2016, Ahuja et al., 2020, Sargent et al., 2012)
	Functionality	This refers to the quality of being useful, practical, and right for which BIM was adopted	(Mohammad et al., 2018)
	Technology quality	This refers to the perception of the degree to which, the BIM technology meets the customer's requirements	(Shehzad et al., 2019)
	Result demonstrability	This refers to the ability of BIM technology to present the result in visualization	(Noor et al., 2018, Wang et al., 2016, Attarzadeh et al., 2015)
	Speed of BIM tools	This refers to the overall time BIM software would take to complete the task	(Shehzad et al., 2019)
	Procurement methods	This refers to type of contract systems used for the execution of projects with the requirements of applying BIM technology	(Shehzad et al., 2019)
	Project complexity	As an intricate arrangement of the varied interrelated parts in which the elements can change and evolve constantly with an effect on the project objectives	(Van Tam et al., 2021, Wang et al., 2016, Ahuja et al., 2020, Sargent et al., 2012)
	Project scale	This refers to the size of a project, the context of the project's complexity, risk and important, and the experience of the organization hosting the project	(Van Tam et al., 2018, Hai & Van Tam, 2019)
	Project requirements	Conditions or tasks which provide a clear picture of the work that must be completed to ensure the success or completion of the project	(Ahuja et al., 2020)
	Stakeholders interaction	This refers to the communication among parties involved in a project.	(Shehzad et al., 2019)
External factors	Stakeholders' awareness	This refers to the knowledge or understanding of parties involved in a project about BIM technology	(Abubakar et al., 2014)
	Government supports	This refers to the action or the recognition of the government in order to provide the right conditions for the implementation of BIM technology	(Mohammad et al., 2018, Attarzadeh et al., 2015)
	Competition levels	The degree of situation in which construction companies are trying to be more successful than each other, including the development of new technology in construction project	(Noor et al., 2018, Wang et al., 2016, Qin et al., 2020, Liu et al., 2010, Attarzadeh et al., 2015)
	Laws and policies	This refers to system of rules, standards, principles, and procedures given by the government to support the implementation of BIM	(Qin et al., 2020, Attarzadeh et al., 2015)
	BIM standards	This refers to the quality of BIM technology that is established by the authority as a model or criterion	(Ezeokoli et al., 2016, Chan, Olawumi, Ho et al., 2019b, Qin et al., 2020, Attarzadeh et al., 2015)
	BIM instructions	This refers to the information and guidance about how to implement BIM software	(Ezeokoli et al., 2016, Chan, Olawumi, Ho et al., 2019b, Qin et al., 2020, Attarzadeh et al., 2015)
	BIM providers	This refers to companies supplying BIM software product	(Noor et al., 2018, Panuwatwanich & Peansupap, 2013, Mohammad et al., 2018, Wang et al., 2016)

Table 3. Demographic of the respondents

Item	Category	Frequency	Percentage (%)
Gender	Male	125	78.62%
	Female	34	78.62%
Education levels	Bachelor's degree	151	94.97%
	Master's degree	7	4.40%
	Doctor's degree	1	0.63%
Work experience	1–5 years	93	58.49%
	6–10 years	35	22.01%
	11–15 years	16	10.06%
	16–20 years	4	2.52%
	Above 20 years	11	6.92%
Organization involvement	Client	10	6.29%
	Authority	5	3.14%
	General Contractor	35	22.01%
	Sub-contractor	23	14.47%
	Supervision	12	7.55%
	Consultant	74	46.54%
Role in construction project	Project manager	29	18.24%
	Site manager	5	3.14%
	Site supervisor	11	6.92%
	Site engineer	13	8.18%
	Designer	39	24.53%
	Architect	25	15.72%
	Estimator	35	22.01%
	Company manager	2	1.26%

4. Results and DISCUSSIONS

In the present study, there are two software applications were applied to examine the findings, which are MS Excel 365 and SPSS 22. A total of 39 factors that affect BIM adoption in the construction project implementation have been identified and ranked based on their descriptive statistics (i.e., mean and standard deviation), and the RII index.

4.1. Human factors group

The ranking of affecting factors relevant to human aspect is given in Seven factors are listed in this category. The surveyed respondents ranked “perceived usefulness” in the first place with RII = 0.758. This factor is also evaluated as the first factor among all 39 factors (Table 9), proving that it has the greatest influence on the BIM adoption of the participants. This result is in line with some previous studies’ opinions (i.e., Hong et al., 2016; Sargent et al., 2012; Shehzad et al., 2019), which indicated that perceived usefulness is a prerequisite factor for users to accept BIM software. “Experience and skills” factor is the second most important factor in human perspective, with RII = 0.734 and ranked fifth place in the overall ranking. This ranking was supported by Shehzad et al. (2019) who explained that limited experience and skills of new technology were mostly affected on BIM intentions to use just right after lack of training and lack of self-efficacy. However, this finding contradicts the result of the study (Attarzadeh et al., 2015) in which, the experience of human resources was ranked 41 over 45 factors. In this regard, “experience and skills” does not frequently affect the intention to use BIM of an individual. With RII = 0.724, “willingness to use BIM” is ranked third in this group and seventh overall, which shows that this factor has a high impact on BIM adoption among participants. This was proved by a study (Chan, Olawumi, Ho et al.,

Table 4. Ranking of factors under human group

Factors	Mean	Std. Deviation	RII	Rank
Perceived Usefulness	3.79	0.977	0.758	1
Experience and skills	3.67	0.898	0.734	2
Willingness to use BIM	3.62	0.966	0.724	3
Work motivation	3.59	1.057	0.718	4
Personal Competency	3.52	0.934	0.704	5
Interest	3.52	0.967	0.704	5
Perceived Ease of use	3.45	0.946	0.690	7

(2019b), which stated that staff willing to improve their market competitiveness by playing a proactive role in learning BIM software. Another factor is “work motivation” (RII = 0.718), which ranked fourth in this group and ninth in the overall ranking, indicating that motivation plays an important role in learning new technology. “Personal competency” and “interest” have the same RII = 0.704, ranking the fifth in this group and 20th among all 39 factors, which indicates that these factors have a low effect on BIM adoption. Finally, “perceived ease of use” with RII = 0.69 was ranked at the end of this category and 29th overall ranking.

4.2. Management factors group

As demonstrated in Table 5, “perceived benefits of BIM for organization” is in the first place in this group with RII = 0.738 and the third in overall ranking, proving that this factor has a significant effect on the application of BIM in a project. This ranking was further supported by the study of (Liu et al., 2010), which stated that perceived benefits is one of the three main factors affecting the AEC industry in BIM adoption, along with external forces and internal readiness. With RII = 0.730, “availability of BIM users” ranked second over 11 management factors and sixth in overall ranking, indicating that skilled staff who can handle BIM tools is important in the decision of using BIM software. This ranking is in line with some previous studies, such as Abubakar et al. (2014) Ahuja et al. (2020), Hong et al. (2016), and Shehzad et al. (2019), which proved that the availability of trained professionals to handle BIM tools was found to be the most significant driver of BIM application. For example, Ahuja et al. (2020) stated that few technically trained employees would assist the adoption of BIM for organizations. Unavailability of BIM users had also been identified as the foremost barrier to the introduction of BIM in the USA (Ku & Taiebat, 2011) and one of the major obstacles in the UK (Khosrowshahi & Arayici, 2012). As for developing countries, a lack of trained professionals was ranked fifth according to the significant study context of Nigeria (Abubakar et al., 2014). By contrast, Qin et al. (2020) indicated that the number of BIM experts and

Table 5. Ranking of factors under management group

Factors	Mean	Std. Deviation	RII	Rank
Perceived benefits of BIM for organization	3.69	0.900	0.738	1
Availability of BIM users	3.65	1.000	0.730	2
Capacity to use information technology	3.56	0.890	0.712	3
Availability of technical infrastructure	3.55	0.972	0.710	4
Organizational readiness	3.53	1.011	0.706	5
Perceived risks	3.49	0.913	0.698	6
Financial resources	3.46	0.979	0.692	7
Manager's support	3.43	0.952	0.686	8
Organization's culture	3.38	0.926	0.676	9
Organization's capacity	3.37	0.932	0.674	10
Organization's policies	3.36	1.002	0.672	11

technical staff had a low influencing degree to aid the adoption of BIM technology as it mainly changed the workflow and pattern of the organizations and had impacts on some human factors (i.e., perceived ease of use, perceived usefulness and intention to use). In this regard, the availability of skilled staff had significant influence on BIM implementation in many countries including Vietnam, except for the case of India mentioned by Qin et al. (2020).

The next three influencing factors are “capacity to use Information technology,” “availability of technical infrastructure” and “organizational readiness” with the RII ranging between 0.706 and 0.712. Although they ranked third, fourth, and fifth compared to other management factors, their rankings overall are 17th, 18th, and 19th, respectively, which indicates that these three factors’ influences were similar and slightly significant to the adoption of BIM. While the study Chan, Olawumi, Ho et al. (2019b) ranked “competent technical support team within company” in the seventh place, this factor was only mentioned by Panuwatwanich and Peansupap (2013) as one of the reasons that would drive the research respondents to adopt BIM. “Organizational readiness” is similar to the previous factor since it was mentioned in the study Hong et al. (2016) as a prerequisite factor to decide BIM adoption, while Shehzad et al. (2019) showed that it was one of the factors with modest influence. Factors such as “perceived risks,” “financial resources,” and “manager’s support” have a moderate impact on BIM adoption with RII between 3.43 and 3.49. “Organization’s culture” (RII = 0.676), “organization’s capacity” (RII = 0.674) and “organization’s policies” (RII = 0.672) were ranked at the end of this group and 33rd, 34th, 35th in overall ranking, indicating that these factors have a low influence on the application of BIM.

4.3. Technological factors group

The ranking of 10 factors under the technological group is shown in Table 6. With RII = 0.75, “speed of BIM tools” was ranked the first in this group and second among all factors, which shows that this factor is a powerful determinant and has a very high effect on BIM usage. This is because the participants believe that speed was the most outstanding and obvious advantage of BIM compared to traditional methods. “Technology quality” (RII = 0.738) was ranked the second in this category and fourth in general ranking, proving that this factor has a significant influence on BIM application. “Functionality” was the third element driving to BIM adoption with RII = 0.72. This factor was also mentioned in Gu and London (2010) as one of the two main areas referred to BIM adoption, including technical tool—functional requirements and need, and the non-technical strategic issues.

“Feasibility using BIM,” “IT support,” and “result demonstrability” were evaluated to have the same effect on BIM adoption as in the respondents’ opinion, with RII = 0.716. They were all ranked fourth in this group and tenth in overall ranking, indicating that the three factors have an important influence on the introduction of BIM technology. According to Wang et al. (2016), poor IT conditions were a huge constraint to technology adoption activity. Meanwhile, “result

Table 6. Ranking of factors under technological group

Factors	Mean	Std. Deviation	RII	Rank
Speed of BIM tools	3.75	0.919	0.750	1
Technology quality	3.69	0.936	0.738	2
Functionality	3.60	0.922	0.720	3
Feasibility using BIM	3.58	0.970	0.716	4
IT support	3.58	0.830	0.716	4
Result demonstrability	3.58	0.963	0.716	4
BIM complexity	3.57	0.918	0.714	7
Accessibility	3.47	0.913	0.694	8
Trialability	3.42	0.937	0.684	9
Procurement methods	3.25	1.006	0.650	10

Table 7. Ranking of factors under project group

Factors	Mean	Std. Deviation	RII	Rank
Project scale	3.58	0.996	0.716	1
Project requirements	3.58	0.957	0.716	1
Stakeholders' awareness	3.57	0.965	0.714	3
Project complexity	3.50	1.043	0.700	4
Stakeholders interaction	3.50	1.012	0.700	4

Table 8. Ranking of factors under external group

Factors	Mean	Std. Deviation	RII	Rank
BIM standards	3.48	0.967	0.696	1
BIM instructions	3.48	0.940	0.696	1
BIM providers	3.43	0.938	0.686	3
Competition levels	3.35	0.969	0.670	4
Laws and policies	3.28	1.038	0.656	5
Government supports	3.12	1.052	0.624	6

demonstrability” was mainly recognized as the ability of BIM in visualization and proved to be the significant advantage of BIM software that drove respondents to try using BIM (Noor et al., 2018). Furthermore, it was stated in the prior study (Wang et al., 2016) that the effortless observability of BIM to organization top management is a contributing factor for BIM adoption. “BIM complexity” with RII = 0.714 is in the seventh place of this group and in the 15th position among 39 factors, indicating that this factor has a moderate impact on BIM adoption.

The other factors in this group are “accessibility,” “trialability,” and “procurement methods” with RII ranging from 0.65 to 0.694, ranking eighth, ninth, and tenth in this category and 27th, 32nd, 38th among all factors, respectively. This proves that these factors have a low influence on the application of BIM.

4.4. Project factor group

The results of Table 7 indicate that five factors of the project group have been ranked by RII index. “Project scale” and “project requirements” with RII = 0.716 were ranked the first in this group and 13th among all 39 factors, which indicates that the two factors have a similar effect on BIM adoption and their influence is moderate. These were closely followed by “stakeholders’ awareness” with RII = 0.714. This ranking is in line with the previous study (Abubakar et al., 2014), which ranked this factor fifth out of 10 drivers, indicating that the awareness of the technology among industry stakeholders was found to be a significant driver of BIM adoption in Nigeria. “Project complexity” and “stakeholders’ interaction” shared the same RII value at 0.7 and was assessed at the end of this group and 22nd among all factors.

4.5. External factors group

Table 8 indicates the ranking of six-factor related to external drivers. The surveyed respondents ranked “BIM standards” and “BIM instructions” (RII = 0.696) in the first position in this group and 20th among 39 factors. Some previous researches, such as Ezeokoli et al. (2016), Chan, Olawumi, Ho et al. (2019b), Attarzadeh et al. (2015), and Qin et al. (2020), have proved the importance of the mentioned factors in the adaptability of BIM. For instance, Ezeokoli et al. (2016) stated that lack of

Table 9. Overall ranking factors influencing BIM adoption

Factors	Mean	Std. Deviation	RII	Rank	Group
Perceived usefulness	3.79	0.977	0.758	1	Human
Speed of BIM tools	3.75	0.919	0.750	2	Technology
Perceived benefits of BIM for organization	3.69	0.900	0.738	3	Management
Technology quality	3.69	0.936	0.738	4	Technology
Experience and skills	3.67	0.898	0.734	5	Human
Availability of BIM users	3.65	1.000	0.730	6	Management
Willingness to use BIM	3.62	0.966	0.724	7	Human
Functionality	3.6	0.922	0.720	8	Technology
Work motivation	3.59	1.057	0.718	9	Human
Feasibility using BIM	3.58	0.970	0.716	10	Technology
IT support	3.58	0.830	0.716	11	Technology
Result demonstrability	3.58	0.963	0.716	12	Technology
Project scale	3.58	0.996	0.716	13	Project
Project requirements	3.58	0.957	0.716	14	Project
BIM complexity	3.57	0.918	0.714	15	Technology
Stakeholders' awareness	3.57	0.965	0.714	16	Project
Capacity to use Information technology	3.56	0.890	0.712	17	Management
Availability of technical infrastructure	3.55	0.972	0.710	18	Management
Organizational readiness	3.53	1.011	0.706	19	Management
Personal Competency	3.52	0.934	0.704	20	Human
Interest	3.52	0.967	0.704	21	Human
Project complexity	3.5	1.043	0.700	22	Project
Stakeholders interaction	3.5	1.012	0.700	23	Project
Perceived risks	3.49	0.913	0.698	24	Management
BIM standards	3.48	0.967	0.696	25	External
BIM instructions	3.48	0.940	0.696	26	External
Accessibility	3.47	0.913	0.694	27	Technology
Financial resources	3.46	0.979	0.692	28	Management
Perceived ease of use	3.45	0.946	0.690	29	Human
Manager's support	3.43	0.952	0.686	30	Management
BIM providers	3.43	0.938	0.686	31	External
Triability	3.42	0.937	0.684	32	Technology
Organization's culture	3.38	0.926	0.676	33	Management
Organization's capacity	3.37	0.932	0.674	34	Management
Organization's policies	3.36	1.002	0.672	35	Management
Competition levels	3.35	0.969	0.670	36	External
Laws and policies	3.28	1.038	0.656	37	External
Procurement methods	3.25	1.006	0.650	38	Technology
Government supports	3.12	1.052	0.624	39	External

BIM standards/guidelines was the reason why most BIM potential remains untapped in Anambra State Nigeria. The same conclusion for Hong Kong has been shown in Chan, Olawumi, Ho et al. (2019b), which indicated that BIM standards are one of the five most significant critical success factors to BIM implementation, therefore, the establishment of BIM industry standards was greatly conducive to BIM adoption. With RII = 0.686, "BIM providers" followed closely to the previous

factors in terms of influence level on BIM application. The remaining factors under the external group are “competition levels,” “laws and policies,” and “government supports,” with RII ranging from 0.624 to 0.67, were ranked at the end of this group, which reveals that these factors have a low effect on the application of BIM.

4.6. Overall ranking critical factors influencing BIM adoption

The overall perceived impacts of all 39 factors were shown in [Table 9](#). As provided, the top five ranking critical factors influencing BIM adoption in construction project are: (1) “perceived usefulness,” (2) “speed of BIM tools,” (3) “perceived benefits of BIM for organization,” (4) “technology quality,” and (5) “experience and skills.” This ranking proves that these five-factor have a significantly important impact on the application of BIM technologies.

Perceived usefulness: It was identified as user’s mindset and intentions towards the use of technology. This factor plays an important role in conducting BIM adoption. This finding is in line with several previous studies (Acquah et al., 2018; Batarseh & Kamardeen, 2017; Hochscheid & Halin, 2019; Sanchís Pedregosa et al., 2020), which showed that perceived usefulness is the most important driver to predict the behavioral intention of using BIM. When respondents observed that BIM was useful, their attitude towards the use of BIM increased and their intention to use BIM increased significantly (Acquah et al., 2018). BIM can be used as an interactive manual for safely managing and operating the building providing complete facility information (Wetzel & Thabet, 2015), such as physical structure, mechanical and electrical systems, furniture, and equipment. BIM models can simulate maintenance or the retrofit process (Khaddaj & Srouf, 2016) and therefore help reduce facility management costs (Love et al., 2015; Zou et al., 2017) and improve the maintenance process as well as provide an accurate cost estimate of renovation (Cheng & Ma, 2013). It can also be used in simulating evacuation scenarios, crowd behavior, and crowd movement (Rüppel & Schatz, 2011).

Speed of BIM tools: It is one of the obvious advantages of BIM software compared with other traditional methods. Ensuring the project duration is a key to improve organization’s reputation and strengthen its competitive advantages. BIM software can help shorten the time, especially in designing phase, improving productivity in general. The speed of BIM tools enables all engineering stakeholders to access data more easily and more effectively to achieve the project goals at an optimum level. It mitigates the time needed for communicating complex ideas exchange of visual information among designers and clients (Xing & Tao, 2015). BIM tools’ speed makes simplified knowledge management. Continuously collected, stored, and maintained project data throughout the building lifecycle streamlines tracking and evaluation of project details (Qian, 2012). BIM tools’ speed makes an immediate and more accurate comparison of different design options, which enables the development of more efficient, cost-effective, and sustainable solutions. The speed of BIM tools can also facilitate the analysis and comparison of various energy performance alternatives to help facility managers dramatically reduce environmental impacts and operating costs (Ghaffarianhoseini et al., 2017).

Perceived benefits of BIM for organization: It is identified in Liu et al. (2010) that the perceived benefit category included quality improvement, improved accuracy, improved access to information, better communication, enhanced ability to compete, integrated work progress, increased profitability, time-saving, reduced claim and law issues, and reduced communication cost. If “perceived usefulness” is considered as a prerequisite factor for users to accept the adoption of BIM tools, “perceived benefits of BIM for organization” is stated to be a motive factor making an organization apply BIM technologies. BIM technology provides optimized platforms for parametric modeling, enabling new levels of spatial visualization, building behavior simulation, effective project management, and operational collaboration of team members. The interoperability capabilities of BIM are more effective when extending its application for construction, facility management, and building maintenance stages. BIM refers to a set of technologies and solutions that can

enhance inter-organizational collaboration and productivity in the construction industry, as well as improving the design, construction, and maintenance practices (Ghaffarianhoseini et al., 2017).

Technology quality: BIM delivers quality assurance to any design and construction project. BIM quality is considered a key factor in improving design quality by eliminating conflicts and reducing rework. Due to the consistency of design data with quality data and construction process with the quality control process, the potential of BIM implementation in quality management lies in its ability to present multi-dimensional data including design data and time sequence (Chen & Luo, 2014). The quality of BIM technology contributes to centralize data and allow for data management across one digital dataset to make quality assurance across design and construction more robust.

Experience and skills: It is accumulated fact from learning and working affect in the case of the same skill or task is repeated more than one time (Mahamid, 2013). The lack of collaboration knowledge, skills, and abilities led to an insufficient understanding of the BIM process, and hence interoperability issues (Oraee et al., 2019). The academic syllabus of Vietnam universities in terms of built environment courses lacks thorough BIM education, it is more common for civil engineering departments rather than architecture. The low levels of education, training, and skill among the workforce have been identified among the most prominent features of construction in developing countries affecting labor productivity (El-Gohary & Aziz, 2014; Hiyassat et al., 2016; Horner et al., 1989; Jarkas, 2015; Mahamid et al., 2013) demonstrated that experience and skill of laborers has a very high impact on construction labor productivity. Hence, the adoption and implementation of BIM tools seem an effective solution to improve productivity of construction industry.

5. Conclusions

The rapid advancement of technology continues to leverage change and innovation in the construction industry. This study aimed to identify a total of 39 factors influencing BIM adoption in construction project implementation, which were grouped into the main 5-category, namely, human, management, technology, project, and external. The data were collected by 159 valid surveyed questionnaires with participants from the construction industry, and these factors were ranked based on their RII index and descriptive statistics (i.e., mean and standard deviation). The findings indicated that the most significant factors affecting BIM adoption in construction project implementation consists of (1) "perceived usefulness," (2) "speed of BIM tools," (3) "perceived benefits of BIM for organization," (4) "technology quality," and (5) "experience and skills."

This study contributes to the topic of factors affecting BIM adoption in construction projects. However, the results of the present study should be considered regarding its limitations. This includes considering the potential lack of awareness of BIM users regarding operational aspects of construction projects, which could be a reason behind some discrepancies with the research outcomes in the past. Another factor limitation to consider is that concerns the fact that the cultural and socio-economic factors of the construction industry might influence the awareness of BIM users. Hence, the outcomes of this study should be generalized in other contexts with caution.

Although numerous researchers have conducted studying factors affecting BIM adoption in many countries from different continents and various valuable results have been concluded from these studies, it seems rather modest compared to a large number of countries and construction projects around the world. Therefore, the authors encourage other researchers to replicate this study in many different areas and countries so that the important factors revealing elsewhere, and the bases platform the related findings can further support the comprehensive theoretical understanding of the more complex problems of this topic area and the critical factors related with specific socioeconomic conditions and cultural backgrounds.

The majority of researches in this area so far was conducted based on perceptions of BIM users only. It is recommended that future directions should consider awareness of construction project

stakeholders to identify and assess the importance levels of factors influencing BIM adoption in the construction industry. It is essential for further studies into the determinant factors in the implementation of different types of construction projects and respondents remain of central interest.

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