ESTABLISHING KEY FACTORS TOWARDS IMPLEMENTING INTEGRATED BUILDING INFORMATION MODELING (BIM) IN AEC INDUSTRY: MALAYSIA STUDY

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Abstract
Building information modeling (BIM) is a systemic approach that enhances the effectiveness and overall quality of construction projects. Integrated BIM (iBIM) is an advanced state of BIM that integrates and synchronizes disparate project data in a centralized database of reliable, accessible and real-time project information. The purpose of this paper is to investigate key factors of iBIM implementation by AEC industry players within the Malaysian context. This study adopted a quantitative method. A questionnaire survey is conducted in Kuala Lumpur, Malaysia, to collect data using 5-level Likert scale questions. The study population was AEC industry players working in firms affiliated with professional institutes in Malaysia. The one-sample T-test and Descriptive Statistics are employed to rank the key factors of iBIM implementation in construction projects. The data were analysed by Statistical Package for the Social Science SPSS software version 20 and Microsoft Excel. It is found that policy factors are the statistically significant factors affecting iBIM implementation in Malaysian construction projects followed by interoperability; learning and education; and finally standardization. Key factors are important as a reference or guideline in advance of selecting the most appropriate framework for achieving successful iBIM implementation in AEC industry.

Keywords: Building Information Modeling, Integrated BIM, Lifecycle, Key Factors, Relative Importance Index.

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INTRODUCTION

With the fast improvement of information and communication technologies (ICT) especially the Internet and Web-based technologies during the past two decades, different integrated and collaborative systems have been adopted to different industries, including AEC industry. Building information modeling (BIM) considers as one of the most ICT effective tools in the AEC industry. BIM within the engineering industry is not new; 3D modeling was adopted in the oil and gas industry since the 1990s (Rogers, Chong, & Preece, 2015). In recent years, BIM emerges as an attractive solution to problems such as errors and rework in pre-construction and construction phases. BIM is expected to dramatically promote overall quality of the construction project information as well the methods that the information is created and exchanged among different project teams (Crotty, 2013; Lu, Zhang, & Rowlinson, 2013). BIM can integrate, maintain and update all the related data of a construction project; to facilitate coordination work through its visualization and clash detection analysis functions; to serve as a collaborative platform for professionals from different disciplines. BIM even plays as the driving-force of integrated project delivery (IPD) (Eastman, Teicholz, Sacks, & Liston, 2011; Gu, Singh, London, Brankovic, & Taylor, 2008b; Singh, Gu, & Wang, 2011; J. E. Taylor & Bernstein, 2009). Besides, the integration of cloud computing technologies with BIM linked the creative working manner that organises communication with the onsite processes. Besides that, it develops enhanced accessibility of project information easily by remotely linking mobile devices with a devoted remote server (Abanda, Mzyece, Oti, & Manjia, 2018).

Recently, BIM has been widely used within AEC industry in Malaysia in order to increase performance and overall quality of the construction projects (Latiffi, Mohd, Kasim, & Fathi, 2013). AEC industry players in Malaysia believe that BIM is the best platform for successful collaboration. Hence, BIM is enforcing gradually to the AEC industry projects in Malaysia (Zakaria, Mohamed Ali, Tarmizi Haron, Marshall-Ponting, & Abd Hamid, 2013). Rogers et al. (2015) indicated that the Malaysian AEC industry organizations have a perception of BIM, which aligns with industry authorities. They revealed that there is a need for effective partnership between the universities and accreditation boards or practice communities. Finally, they also found that market demands were the main drivers to adopt BIM within few years in Malaysian AEC industry, as well as increasing awareness in BIM and the competitiveness advantage (Rogers et al., 2015). Another study was done by CIDB Malaysia in 2016, which measured the level of BIM adoption within Malaysian AEC industry. It indicated that there is a prevalent awareness of BIM among the professionals in AEC industry in Malaysia. 84% of their survey responses were ready to adopt BIM technology, while the percentage of BIM adopters was extremely low with 17%. Finally, a total of 96% of the respondents believe that BIM will provide benefits to their organisation (CIDB, 2017). In this context, the future application of BIM is expected to expand in Malaysian AEC industry.

LITERATURE REVIEW

The BIM Maturity Levels

AEC industry is driven by players to accomplish higher levels of BIM maturity by demanding technological innovations and process improvements that increase sustainability as well as reduce costs (Systèmes, 2014). The levels of BIM maturity in the AEC industry in the United Kingdom have been categorized by Bew and Richards (2008) into "4 levels" as illustrated in figure 1. It begins with projects using hard copy drawing, to those using the fully integrated web-based database.

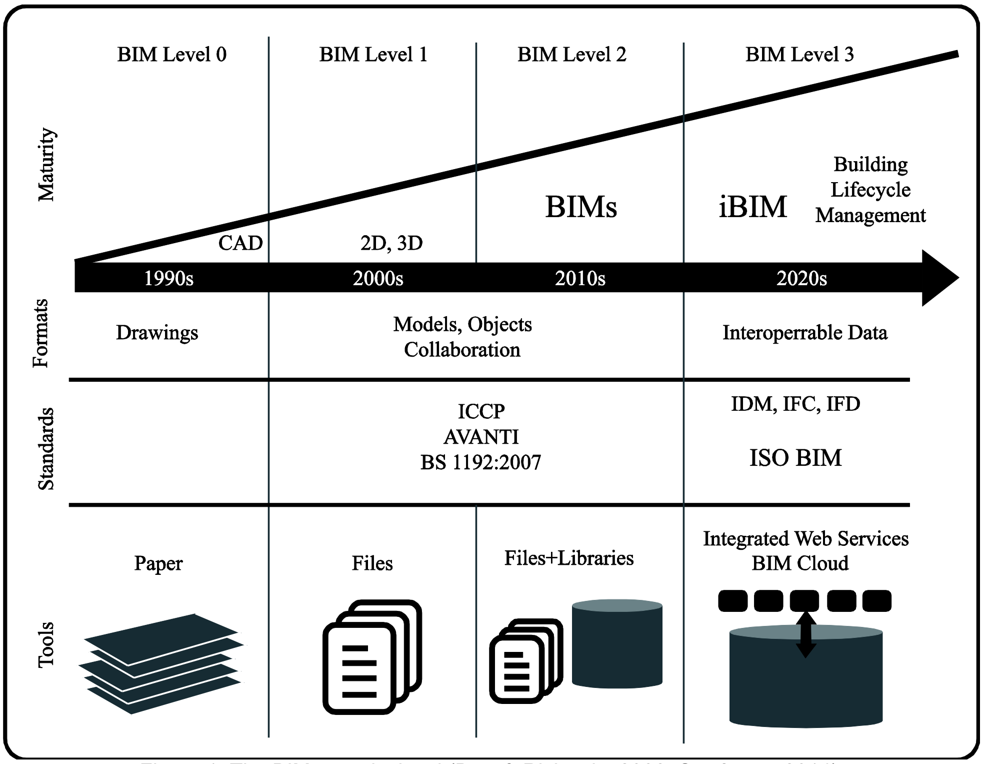

Figure 1: The BIM maturity level (Bew & Richards, 2008; Systèmes, 2014)

At Level 0, 2D drawings are used, despite this 2d drawing created using CAD, the sharing of these 2D drawings in papers, it is fundamentally the use of CAD tools to generate drawings and drawn components using ICT applications. In level 1, 3D and 2D drawings created by CAD. The data may be accessible to the project team; Level 1 proceed from CAD to create suites of 2d information, as well as non-federated 3D models. Level 2 store and synchronize data in particular BIM platform, all data and information are held separately, this is called sometimes as "federated Model" because it comprises several discrete models produced by individual members of the project team. Federation takes place with a shared online area known as Common Data Environment. In level 3, all the information stored in an integrated system. Only authorized individuals can access this web-based system. Level 3 envisages a wholly integrated project information model, hosted and fully developed in a Common Data Environment in real-time. This data could be extracted for further use, such as building lifecycle management.

According to Systèmes (2014), BIM maturity level in the UK seems to be shifting from Level 1 to Level 2. However, some organizations are seeking to search for benefits with BIM Level 2 processes. The involvers are researching for leveraging toward integrated BIM (BIM Level 3) implementation.

Moreover, teams that successfully implement BIM Level 3 processes get from substantial benefits; a less rework and waste created; less time in delivering; and get better outcomes.

Integrated BIM –iBIM

According to Häkkinen and Kiviniemi (2008), iBIM is a repository of all BIM models containing the information of a building covers not only geometry, spatial relationships, geographic information, and quantities. Furthermore, quantities and shared properties of materials can be extracted. It can be used to represent the entire lifecycle of the building, including the processes of construction and facility operation. Moreover, it can be used as a source of information for analysis of the solution as well as to store the results of analysis (C. Taylor et al., 2009). The process of establishing iBIM is accumulating, expanding, integrating and applying the building lifecycle management (BLM). By integrating each stage or sub-information model created by each application to form a complete BIM. iBIM solves the storage and distribution of the fragmented information and models, sharing and coordination issues. Process and organization management provides support for BIM information creation, access, and data maintenance (Wang, 2017). Construction organizations that implement iBIM successfully can benefit from the significant advantages as they deliver in less time, produce less waste, and create better results while retaining a healthy profit margin (Systèmes, 2014). Mainly, iBIM offers; real-time monitoring of progress; coordination; automated clash detection and information sharing among teams of a construction project regardless of location. (Abanda et al., 2018).

Key factors of iBIM implementation

Key factors are about the limited number of factors that influence the end outcomes and increase the opportunity of achieving intended objectives if addressed significantly (Enegbuma & Ali, 2011; Rockart, 1979). Key factors are very important as a reference or guideline in advance of selecting the most suitable or appropriate framework for achieving successful collaboration using iBIM (Nawi, Lee, Kamar, & Hamid, 2012). Despite the fact that each country adopts a various combination of key factors, some global key factors are shared among these countries (Antwi-Afari, Li, Pärn, & Edwards, 2018). Table 1 summarizes the key factors based on the literature, the details of these key factors described below.

Standardization

Standards and technical procedures of practice such as using interoperable programs and applying authentic ways of sharing information are widely utilized to promote integrated teams in AEC industry (Homayouni et al., 2010). To implement BIM, coordination methods among project teams as well as standardizing building components and the attributes associated with those components are substantial for better results (Eastman et al., 2008). However, AEC industry players adopt BIM based on their definition. These lead to low-efficiency cooperation among construction project players. Hence, there is a need for BIM guidelines and process to be standardized in order to implement iBIM successfully (Azhar et al., 2011; Shang & Shen, 2014). Standards are important to be established as well as technical procedures to promote iBIM among integrated teams within AEC industry, such as interoperable software and mutual exchange file formats. Furthermore, the development of technical procedures and standards to utilize iBIM will lead to a more seamless collaborative environment as well as less problematic (Homayouni et al., 2010).

Policy

The purpose of policies is to increase the productivity of iBIM by supporting the quality of information delivered to players of construction project during the lifecycle. Moreover, to implement iBIM on construction projects, it is necessary to adopt policies that provide a clear vision of project delivery methods, the quality of processes and consistency of information within AEC industry (Kassem, Iqbal, Kelly, Lockley, & Dawood, 2014). On another point of view, Succar (2009) identify policy field as one of the most important conceptual parts of BIM activities. Its focus on distributing benefits, delivering research, preparing participants, minimizing conflicts and allocating risks in the construction projects. These players do not produce any construction output. Still, they are specialized parties, such as research centres, insurance companies, regulatory bodies, and educational institutions, which play a substantial regulatory, contractual and preparatory roles in the pre-construction, construction and post-construction process (Succar, 2009). Hence, AEC industry organisations should pay more attention to the practice of their profession. Economic benefits should be shared by AEC industry organisations to adopt iBIM processes successfully (Liu et al., 2017).

Interoperability

The transmission of exchange process from paper-based to process-based for design models, lead to a dramatic shift in AEC industry by enhancing the application of digital models (Steel, Drogemuller, & Toth, 2012). Indeed, it is essential for BIM success in any construction building to share information without any damage information. Both researchers and professionals have found that one of the solutions to successful iBIM implementation is interoperability (Abanda et al., 2018). Golabchi and Kamat (2013) define interoperability as the capability of several components or systems to share information and exchange that can be utilized for different purposes. Regardless of the software, interoperability as a term is utilized to explain the ability of various programs for data exchange by using widespread exchange formats sets.

Training and Education

AEC industry players with various backgrounds and cultures may have major different BIM experience; this difference will lead to an accurate outcome. AEC organizations must look for trends to soften the learning and training curve of BIM practitioners (Azhar et al., 2011; Shang & Shen, 2014). Moreover, BIM learning aspects should be created based on various requirements, starting from standard and universal to advanced and specified. However, like any technical education, construction education needs to be updated to the current date. One of the principles in construction education is to teach new technologies such as BIM and merge it into the curriculum (Abbas, Din, & Farooqui, 2016; Ahbab, Rezaei, & Sistani, 2013).

Table 1: Key factors towards iBIM implementation in AEC industry

No.	**Key factors**	C. Taylor et al. (2009)	Succar (2009)	Homayouni et al. (2010)	Eastman et al. (2011)	Deutsch (2011)	Enegbuma and Ali (2011)	Nawi et al. (2012)	Redmond et al. (2012)	Shang and Shen (2014)	Hardin and McCool (2015)	Liu et al. (2017)
1	Standardization	•	•	•	•		•		•	•	•	
2	Policy		•	•		•	•	•		•		
3	Interoperability	•	•		•	•			•			
4	Training and education	•	•		•	•	•		•	•	•	•

METHODOLOGY

The research methodology includes an extensive literature review, sampling, pilot study, data collection and analysis. Quantitative method was adapted in this study by using the survey approach. A questionnaire survey was conducted to collect data among AEC industry players that working in firms affiliated with professional institutes in Kuala Lumpur, Malaysia (i.e. Board of Architects Malaysia (LAM), Construction Industry Development Board Malaysia (CIDB), Board of Quantity Surveyors Malaysia (BQSM), such as (architects, engineers, quantity surveyors, project managers, contractors and suppliers). A pilot test was conducted for the questionnaire by 32 academics and practitioners to ensure the statistical reliability and validity of the questionnaire as well as 5 participants for face validity. Usually, Pilot study for the survey helps in determining the capability of individuals of completing the survey and their understanding of the questions (Creswell, 2012). The initial draft of the questionnaire was derived from the literature review. Several revisions were made to construct an understandable and applicable questionnaire. After that, the final questionnaire was sent by email to the respondents using electronic surveys. The five-point Likert scales (1 = totally disagree), to (5= totally agree) were used to answer the survey questions. 1000 questionnaires were sent out to the participants, and only 322 valid questionnaires were returned with a response rate of 32.2%. The Statistical Package for the Social Science (SPSS) software version 20.0 and Microsoft Excel were employed to analyze the collected data. For the analysis and data presentation, the one-sample T-test and descriptive statistics test were used, which include; arithmetic means, Standard deviation (SD), Relative Importance Index (RII), and finally ranks. Next section shows the analysis of the questionnaire survey, including the respondents' profile.

RESULTS AND DISCUSSION

The demographics result reveals that 54.3% of the respondents have "less than 5 years" experience of working within the Malaysian AEC industry. The years of experience of the rest of the respondents are "from 5 to less than 10 years" with 23.6%, "from 10 to less than 15 years" with 9.3%. "from 15 to less than 20 years" with 5.0% and finally "20 years and more" with 7.7%. There are 92 Civil Engineers (28.6%), 84 Architects (26%), 51 MEP Engineers (15.8%), 29 Project manager (9%), 25 Quantity surveyor (7.8%), 15 Contractor (4.7%), 19 technical assistant (5.9%) and 7 from other specializations (2.1%) including Owners, Surveyor, Environmental Engineers, and GIS Engineers. From the 322 Respondents who completed the questionnaire, 209 are BIM users, while the rest 113 are non-BIM users. Table 2 shows the Respondents profile as follows:

Table 2: The Profile of Respondents

Respondents demography	Categories	Frequency	Percentage
Gender	Male	98	30.4%
	Female	224	69.6%
Educational qualification	Diploma	31	09.6%
	Bachelor	200	62.1%
	Master's	80	24.8%
	PhD.	11	03.4%
Profession	Architect	84	26.0%
	Civil Engineer	92	28.6%
	MEP Engineer	51	15.8%
	Project Manager	29	09.0%
	Quantity Surveyor	25	07.8%
	Contractor	15	04.7%
	Technical Assistant	19	05.9%
	Other	7	02.1%
Years of experience	Less than 5 years	175	54.3%
	5 to less than 10	76	23.6%
	10 to less than 15	30	09.3%
	15 to less than 20	16	05.0%
	More than 20 years	52	07.7%
BIM experience	BIM User	209	64.9%
	Non-BIM user	113	35.1%

In this study, 12 items were adapted by reviewing the literature and validated depending on the pilot study of the questionnaire survey, as mentioned in the research methodology section. The respondents rated these items according to their opinions. Table 3 presents the descriptive statistics such as means SD, RII, T-value, P-value and ranks.

Policy

The findings indicated that "BIM practices should be paid more attention by AEC industry organizations" (PO2) is the strongest factor within the policy category. The ranking of this item is the first with (RII = 79.00%; SD=1.05, P-value = 0.00*). This result indicates that most of the respondents agreed that BIM practice should pay more attention. This finding is in line with Liu et al. (2017) study, where they pointed out that organization policy should focus on installing the software, upgrading the hardware, training their professional for BIM use. Indeed, there is a need for restructuring workflows and design process. Hence professionals can only experience more job impacts when the BIM implementation in their organization becomes at an advanced level; because it requires more adjustments and changes related to the professionals' working patterns and routines. In this case, the individual will receive more job impact and principal support, especially from the senior managers.

"The policies in organizations should support the use of iBIM for effective collaboration." (PO1) is the second in ranking with (RII = 78.20 %; SD=1.06, P-value = 0.00*). This finding is consistent with the findings of the studies of Succar (2009) and Kassem et al. (2014). They indicate that the goal of policies is to improve the productivity of iBIM by fostering the information quality and the delivered data to the involved players in a lifecycle of a construction project.

Table 3: The results of the key factors of iBIM implementation in Malaysian AEC industry

Key Factors	Code	Item	Mean	SD	RII%	T – value*	Sig. (2-tailed)	Ranking
Policy	PO2	BIM practices should be paid more attention by AEC industry organizations	3.96	1.05	79.0%	16.28	0.00*	1
	PO1	The policies in organizations should support the use of iBIM for effective collaboration	3.91	1.06	78.2%	15.36	0.00*	2
	PO4	The top-level of management should give considerable control to the BIM team to explore, discuss, and challenge ideas	3.90	1.09	78.0%	14.79	0.00*	3
	PO3	iBIM administration should deals with top management of model access rights, data control and security	3.77	1.07	75.5%	12.95	0.00*	4
Interoper-ability	IP1	iBIM should provide a centralized data repository for the project	3.89	1.04	77.8%	15.33	0.00*	1
	IP2	Interoperability is important in enhancing the use of iBIM technology	3.82	1.03	76.3%	14.15	0.00*	2
Learning and education	LE2	Open-source training materials such as technical support for iBIM tools	3.82	1.05	76.5%	13.96	0.00*	1
	LE3	Create strategic alliances with organizations that have the requisite BIM experience	3.82	1.06	76.4%	13.86	0.00*	2
	LE1	iBIM learning should be supported with support tools that include help menus, FAQs and helpdesk	3.72	1.06	74.4%	12.16	0.00*	3
Standard-ization	ST1	iBIM should supported by stimulating standards within AEC industry	3.80	1.02	76.0%	13.91	0.00*	1
	ST3	Integrated project delivery (IPD) is the best method to facilitate the collaboration using iBIM	3.77	1.04	75.4%	13.21	0.00*	2
	ST2	iBIM should supported by neutral data exchange formats such as IFC format	3.69	1.05	73.9%	11.79	0.00*	3
		Total	3.82	1.05	76.4%			

***T-test value = 3 at significance level 0.05 (2-tailed)**

"The top level of management should give considerable control to the BIM team to explore, discuss, and challenge ideas." (PO4) is the third in ranking with (RII of 78.0%; SD=1.09, P-value = 0.00*). the overall mean is 3.90. This result is supported by (Liu et al., 2017; Nawi et al., 2012), they indicate that leadership is important for effective collaboration among teams by doing more than obtain knowledge from the other organization and apply it. Hence, the top management should appropriately manage the individual professionals' positive attitudes toward iBIM by frequently communicating with them, involving them in the implementation process and advancing the BIM paradigms generally.

"iBIM administration should deal with top management of model access rights, data control and security" (PO3) is the fourth in ranking with (RII = 78.20 %; SD=1.06, P-value = 0.00*). This result is supported by Liu et al. (2017) study; they explain that when the model is ready around the viewing, sharing, administrating and storing domain, collaboration is critical due to the increasing need for model sharing with practitioners and growing iBIM obligations as well. Thus, the management of the model including creation, sharing and controlling, leads to successful iBIM implementation.

Interoperability

"iBIM should provide a centralized data repository for the project" (IP1) is the first in ranking with (RII of 77.8%; SD=1.04, P-value = 0.00*). This finding echoes the study by Tarandi (2015), implying that the integrated model of the iBIM with a single central database is substantial for integration, versioning and consolidation. Redmond et al. (2012) further stated that linking the heterogeneous applications with a central repository platform is the possible solution for information exchange issues. Hence, project information could be accessed and exchanged seamlessly, as well as improve project understanding and control; thereby, iBIM could become a powerful management tool. On the other hand, the respondents explained that besides having a central server or common data environment in order to let the BIM models and data to live in, a collaborative project procurement method is also crucial to enhance the collaboration.

"Interoperability is important in enhancing the use of iBIM technology"(IP2) is the second in ranking with (RII of 76.3%; SD=1.03, P-value = 0.00*). This finding is supported by Eastman et al. (2011), they indicate that in most surveys related to BIM, interoperability is the largest key factor for advanced BIM users. Moreover, Hoeber and Alsem (2016) explain that the interoperability lead to fewer errors, rework and other problems for transactions of information. This raises the necessity to implement iBIM approach, which comprises the method to exchange data or communicate between project teams. The standards and protocols are necessary to enable the interoperability of different BIM systems. The respondents further suggest to improve the infrastructure in Malaysia (Internet's coverage & speed) for better cloud interoperability for effective iBIM implementation within Malaysian AEC industry.

Learning and Education

The first in ranking is "Open-source training materials such as technical support for iBIM tools" (LE2) with (RII of 76.5%; SD=1.05, P-value = 0.00*). Singh et al. (2011) stress that open-source training materials are very important for iBIM as technical support, where users can gain knowledge and learn from others' experience.

The second in ranking is "It is important to create strategic alliances with organizations that have the requisite BIM experience" (LE3) (RII of 76.4%; SD=1.06, P-value = 0.00*). This resonates with the study made by Bedwell et al. (2012), collaboration in iBIM can occur in joint ventures and strategic partnerships among organizations, where alliances may be arranged in closeness to promote the knowledge transfer and skills that can facilitate successful collaboration (Bedwell et al., 2012). Thus, the coordination between planning strategies and human resource structures is a key solution for supporting iBIM implementation effectively.

"iBIM learning should be supported with support tools that include help menus, FAQs and helpdesk" (LE1) is the third with (RII of 76.0%; SD=1.02, P-value = 0.00*). This result is in line with Abbasnejad, Nepal, and Drogemuller (2016) study, they explain that during iBIM implementation, additional training and e-learning support should be there for employees and managers. A support that can be provided either by inside teammates or outside companies such as helpdesk is critical to meet iBIM users' needs after initial implementation.

Standardization

The first in the ranking is "iBIM should supported by stimulating standards within AEC industry" (ST1) with (RII of 74.4%; SD=1.06, P-value = 0.00*). This result is consistent with Gu, Singh, London, Brankovic, and Taylor (2008a) study; they reveal the importance of simulating Standards that relate to version management such as what data-subsets to generate, how to maintain the history, and so on have emerged repetitively and how to structure model hierarchy for effective application. Azhar, Hein, and Blake (2011) further emphasis that there is a need to define the guidelines for iBIM implementation standardize its process as well.

"Integrated project delivery (IPD) is the best method to facilitate the collaboration using iBIM" (ST3) is the second in ranking with (RII of 75.4%; SD=1.04, P-value = 0.00*). This finding is supported with Sebastian (2011) study; he explains that IPD is a sophisticated method in order to facilitate and to encourage an integrated and open collaboration with BIM support throughout the lifecycle of the construction project. In general, IPD embraces intensive collaboration as well as clear communication among the teams of the construction project, which gives the project advantage to implement iBIM.

"iBIM should be supported by neutral data exchange formats such as IFC format." (ST2) is the lowest factor in the ranking with (RII = 73.9%; SD=1.05, P-value = 0.00*). It proves that respondents have a high awareness about the iBIM data exchange process and formats such as IFC which already consider one of the effective solutions for standardization issues.

Finally, according to the respondents' opinions, iBIM key factors seem to be acceptable as the strongest key factors of iBIM implementation. Findings show that the overall mean 3.82 and the overall RII is 76.45%, which is greater than 60% (whereas the RII neutral is (3/5)*100 = 60%). Also, the test value of t at significance level = 0.05 is 3, whereas the values of t-test for all items are significant, which is greater than the test value of t (3). Also, the total P-value of all statements equals 0.00* which is less than the significance level (0.05). Based on this result, these key factors are significantly important for iBIM implementation in construction projects. To implement iBIM successfully in AEC industry, players should focus on all above mentioned key factors and find ways to enhance the achievement of each key factor. This will make the construction firms go through the implementation of iBIM with an elevated level of confidence to reach their target.

As shown in Table 4, The overall result shows that key factors are significant and ranked as following; the first is "Policy' with an overall mean score of 3.83 (RII%=77.7%, SD=1.06); followed by 'Interoperability' with an overall mean score of 3.85 (RII%=77.1%, SD=1.03); 'Learning and Education' is ranked the third with an overall mean score of 3.79 (RII%=75.8%, SD=1.06); finally, 'Standardization' ranked the fourth with an overall mean score of 3.75 (RII%=75.1%, SD=1.04). The findings show that the respondents have a sense of the significance of the key factors of iBIM implementation within AEC industry in Malaysia.

Table 3: The overall results for key factors of iBIM implementation

Key Factors	Total Mean	Total SD	Total RII%	Ranking
Policy	3.88	1.06	77.7%	1
Interoperability	3.85	1.03	77.1%	2
Learning and education	3.79	1.06	75.8%	3
Standardization	3.75	1.04	75.1%	4
Total	3.82	1.05	76.4%	

The present study identified key factors of iBIM implementation within AEC industry, which can lead to the development of a suitable framework for iBIM implementation. Four main components, namely Policy; Interoperability; Learning and Education; and standardization, were comprised with sub-factors for each. Key factors are important as a reference or guideline in advance of selecting the most appropriate framework for achieving successful iBIM implementation within AEC industry. Next section summarizes the present study and introduces a set of recommendation and future trends regarding iBIM implementation within AEC industry.

CONCLUSION

This research deal with a major ICT trending which is known as BIM that acknowledges as one of the important aspects in the Malaysian AEC industry. BIM is a systemic approach that could enhance environmental sustainability, efficiency, and quality of AEC projects. Currently, iBIM process enables major construction teams to collaborate in a single iBIM cloud database. Multi disciplines team members from all over the continents can participate and cooperate effectively on a single project, despite the different time zones and places. Files management and automated clash detection will increase the concentration on the design, coordination and optimized procurement. This study focuses mainly on the key factors of iBIM implementation regardless of the different disciplines in the project lifecycle within the Malaysian AEC industry. Different researchers have tried to identify the factors for a successful project for a long time. Key factors have been mentioned in the literature. Several journals in the construction field are chosen to review of previous works on iBIM implementation. Four key factors, namely Policy; Interoperability; Learning and Education; and standardization, are identified as crucial to iBIM implementation success.

A questionnaire form is designed based on these factors. Data are obtained from the professionals who are working in firms affiliated with professional institutes in Malaysia. (i.e. Board of Architects Malaysia (LAM); Construction Industry Development Board Malaysia (CIDB); Board of Quantity Surveyors Malaysia (BQSM); and those who work for leading AEC companies in Malaysia, classified as potential respondents. It is found that policy factors are the statistically significant factors affecting iBIM implementation in Malaysian construction projects followed by interoperability; learning and education; and finally standardization. The respondents show positive responses toward the key factors of iBIM implementation and advancing the BIM paradigms generally.

Finally, it is recommended that future research could utilize other statistical methods such as Confirmatory factor analysis (CFA) to analyze the quantitative data, which may provide findings that are more relevant to the real situation. Moreover, other studies can experiment other factors that the current study not included. Key factors are very important as a reference or guideline in advance of selecting the most suitable or appropriate framework for achieving successful iBIM implementation. To implement iBIM in the AEC industry effectively, a better understanding of the mechanism for these key factors by professionals is substantial. Although key factors have been validated through questionnaire survey by BIM experts, more effort will be made to develop a framework further to cover wider components and factors based on real BIM-Based projects.

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References

Abanda, F., Mzyece, D., Oti, A., & Manjia, M. (2018). A Study of the Potential of Cloud/Mobile BIM for the Management of Construction Projects. Applied System Innovation, 1(2), 9.
Abbas, A., Din, Z. U., & Farooqui, R. (2016). Integration of BIM in Construction Management Education: An Overview of Pakistani Engineering Universities. Procedia Engineering, 145(Supplement C), 151-157. doi: https://doi.org/10.1016/j.proeng.2016.04.034
Abbasnejad, B., Nepal, M., & Drogemuller, R. (2016). Key enablers for effective management of BIM implementation in construction firms. Paper presented at the Proceedings of the CIB World Building Congress 2016: Volume I-Creating built environments of new opportunities.
Ahbab, C., Rezaei, A., & Sistani, N. S. (2013). Integration of building information modeling into the undergraduate curriculum: Case of Eastern Mediterranean University.
Antwi-Afari, M., Li, H., Pärn, E., & Edwards, D. (2018). Critical success factors for implementing building information modelling (BIM): A longitudinal review. Automation in Construction, 91, 100-110.
Azhar, S., Hein, M., & Blake, S. (2011). Building information modeling (BIM): Trends, Benefits, Risks, and Challenges for the AEC Industry. Leadership and Management in Engineering, 11(3), 241-252.
Bedwell, W. L., Wildman, J. L., DiazGranados, D., Salazar, M., Kramer, W. S., & Salas, E. (2012). Collaboration at work: An integrative multilevel conceptualization. Human Resource Management Review, 22(2), 128-145.
Bew, M., & Richards, M. (2008). BIM maturity model. Paper presented at the Construct IT Autumn 2008 Members' Meeting. Brighton, UK.
CIDB. (2017). Malaysia Building Information Modelling Report 2016 Technical Report Publication No. 1217.
Creswell, J. W. (2012). Educational research. Planning, conducting, and evaluating quantitative and qualitative research.
Crotty, R. (2013). The impact of building information modelling: transforming construction: Routledge.
Deutsch, R. (2011). BIM and integrated design: strategies for architectural practice: John Wiley & Sons.
Eastman, C., Teicholz, P., Sacks, R., & Liston, K. (2011). BIM handbook: A guide to building information modeling for owners, managers, designers, engineers and contractors: John Wiley & Sons.
Enegbuma, W. I., & Ali, K. N. (2011). A preliminary Critical Success Factor (CSFs) analysis of Building Information Modelling (BIM) implementation in Malaysia. Paper presented at the Proceedings of the Asian Conference on Real Estate Sustainable Growth, Management Challenges.
Gu, N., Singh, V., London, K., Brankovic, L., & Taylor, C. (2008a). Adopting building information modeling (BIM) as collaboration platform in the design industry. Paper presented at the CAADRIA 2008: Beyond Computer-Aided Design: Proceedings of the 13th Conference on Computer Aided Architectural Design Research in Asia.
Gu, N., Singh, V., London, K., Brankovic, L., & Taylor, C. (2008b). BIM: Expectations and a reality check. Paper presented at the Proceedings of 12th International Conference on Computing in Civil and Building Engineering & 2008 International Conference on Information Technology in Construction.
Häkkinen, T., & Kiviniemi, A. (2008). Sustainable building and BIM. Paper presented at the Proceedings of SB08 Conference Melbourne.
Hardin, B., & McCool, D. (2015). BIM and construction management: Proven tools, methods, and workflows: John Wiley & Sons.
Hoeber, H., & Alsem, D. (2016). Life-cycle information management using open-standard BIM. Engineering, Construction and Architectural Management, 23(6), 696-708. doi: 10.1108/ecam-01-2016-0023
Homayouni, H., Neff, G., & Dossick, C. S. (2010). Theoretical categories of successful collaboration and BIM implementation within the AEC industry. Paper presented at the Construction Research Congress 2010: Innovation for Reshaping Construction Practice.
Kassem, M., Iqbal, N., Kelly, G., Lockley, S., & Dawood, N. (2014). Building information modelling: Protocols for collaborative design processes. Journal of Information Technology in Construction (ITcon), 19, 126-149.
Latiffi, A. A., Mohd, S., Kasim, N., & Fathi, M. S. (2013). Building information modeling (BIM) application in Malaysian construction industry. International Journal of Construction Engineering and Management, 2(A), 1-6.
Liu, Y., van Nederveen, S., & Hertogh, M. (2017). Understanding effects of BIM on collaborative design and construction: An empirical study in China. International Journal of Project Management, 35(4), 686-698. doi: https://doi.org/10.1016/j.ijproman.2016.06.007
Lu, W., Zhang, D., & Rowlinson, S. (2013). BIM collaboration: A conceptual model and its characteristics. Paper presented at the Proceedings of the 29th Annual Association of Researchers in Construction Management (ARCOM) Conference.
Nawi, M. N. M., Lee, A., Kamar, K. A. M., & Hamid, Z. A. (2012). Critical success factors for improving team integration in Industrialised Building System (IBS) construction projects: The Malaysian case. Malaysian Construction Research Journal, 10, 44-62.
Poirier, E., Forgues, D., & Staub-French, S. (2017). Understanding the impact of BIM on collaboration: a Canadian case study. Building Research & Information, 45(6), 681-695. doi: 10.1080/09613218.2017.1324724
Redmond, A., Hore, A., Alshawi, M., & West, R. (2012). Exploring how information exchanges can be enhanced through Cloud BIM. Automation in Construction, 24, 175-183.
Rockart, J. F. (1979). Chief executives define their own data needs. Harvard business review, 57(2), 81-93.
Rogers, J., Chong, H.-Y., & Preece, C. (2015). Adoption of building information modelling technology (BIM) perspectives from Malaysian engineering consulting services firms. Engineering, Construction and Architectural Management, 22(4), 424-445.
Sebastian, R. (2011). BIM in different methods of project delivery. Paper presented at the Proceedings of the CIB W78-W102: International Conference. , France
Shang, Z., & Shen, Z. (2014). Critical Success Factors (CSFs) of BIM Implementation for Collaboration based on System Analysis Computing in Civil and Building Engineering (2014) (pp. 1441-1448).
Singh, V., Gu, N., & Wang, X. (2011). A theoretical framework of a BIM-based multi-disciplinary collaboration platform. Automation in Construction, 20(2), 134-144. doi: https://doi.org/10.1016/j.autcon.2010.09.011

Succar, B. (2009). Building information modelling framework: A research and delivery foundation for industry stakeholders. Automation in Construction, 18(3), 357-375.
Systèmes, D. (2014). End-to-end collaboration enabled by BIM level 3. White paper by Dassault Systemes published online at http://www. 3ds. com/industries/architecture-engineering-construction/resourcecenter/white-papers/end-to-end-collaboration-enabled-by-bim-level-3.
Tarandi, V. (2015). A BIM collaboration lab for improved through life support. Procedia Economics and Finance, 21, 383-390.
Taylor, C., Gu, N., London, K., Singh, V., Tsai, J., Brankovic, L., . . . Mitchell, J. (2009). Final Report Collaboration Platform: Research report for CRC Construction Innovation.
Taylor, J. E., & Bernstein, P. G. (2009). Paradigm trajectories of building information modeling practice in project networks. Journal of Management in Engineering, 25(2), 69-76.
Wang, Y. (2017). Research on the Assembly Building Integrated Construction System Based on BIM. Revista de la Facultad de Ingeniería, 32(5).
Zakaria, Z., Mohamed Ali, N., Tarmizi Haron, A., Marshall-Ponting, A., & Abd Hamid, Z. (2013). Exploring the adoption of Building Information Modelling (BIM) in the Malaysian construction industry: A qualitative approach. International Journal of Research in Engineering and Technology, 2(8), 384-395.