BUILDING INFORMATION MODELLING (BIM) FOR SUSTAINABLE INDUSTRY: THE MALAYSIAN ARCHITECT'S PERSPECTIVE

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ABSTRACT

The Malaysian construction industry is steadily gearing its way towards the adoption of Building Information Modelling (BIM). Subsequently, architects hold a significant role being one of the key players in the industry. Despite rapid development, BIM adoption within the industry is extremely low and only a few organisations are putting it into practice. Previous research has enumerated a broader aspect of BIM in the context of the construction industry holistically, but merely a small number concentrate specifically on local architects thus forming a knowledge gap. Therefore, this paper focused primarily on addressing the minimal BIM adoption amongst architects by exploring its current utilisation, benefits and driving factors as well as awareness. The study was quantitative, whereby a survey was created to study the trends and elicit the opinions of architects. The findings consequently showed that the current BIM usage was still low, with majority of the architects displaying moderate level of awareness. Several driving factors were identified relating to people, process, policy and technology which should be addressed in the future. This study would provide the industry with invaluable insight regarding BIM adoption and serve as a critical reference in assessing the changes and effects of its progress in Malaysia.

Keywords: *: Building Information Modelling, BIM Adoption, Malaysian Architecture Industry*

1. INTRODUCTION

The Malaysian construction industry is projected to grow by at least 10.3% for the year 2018. In order to achieve the projected growth rate, the annual demand for construction sector is projected at RM180 billion (CIDB, 2014). Subsequently, the local architectural service sector serving as one of the key players is attributed to contribute their momentous role in the country's economic development. Building Information Modelling (BIM) is regarded as the future of the construction industry in which its potential use will result in greater benefits such as reduced construction delay, cost reduction, smoother project coordination, increased productivity and a better control of design projects (Gardezi, Shafiq, Nuruddin, Farhan & Umar, 2014). The uptake of BIM would transform the local industry into a highly productive and sustainable landscape in line with the strategic Vision 2020. To date, BIM has been associated with a rapid expansion process through numerous initiatives and programmes planned by public and private bodies alike. As stated in the Construction Industry Transformation Plan (CITP), the industry is aiming to transform the domestic construction industry and achieve level 2 of BIM maturity by the year 2020. This will be reflected in a minimum of 40% of implementation rate for public projects valued at RM100 million and above (CIDB, 2017). Some of the key objectives is increasing the number of highly trained BIM manpower, underlining the adoption of BIM protocols by the Local Authorities (PBT), enhancing BIM resources, enforcement of numerous pilot projects and facilitating BIM adoption programmes for the industry (CIDB, 2017). However, BIM adoption in the Malaysian construction industry is still lagging behind other developing countries despite the multitude of benefits identified (CIDB, 2017; Zahrizan, Ali, Haron, Marshall-Pointing & Hamid, 2014; Gardezi et al., 2014). According to the latest national BIM report by CIDB, despite extensive awareness and willingness of construction players to adopt BIM, the percentage of its adopters are extremely low at 17%. A majority of them are still reporting a low exposure to BIM usage, including the architects, whereby the implementation remains dependable on 2D drafting and the single disciplinary use of 3D modelling (CIDB, 2017). Currently, there is no tangible case study or report highlighting the benefits of BIM, superimposed with the industry's difficulties in understanding the benefits of putting it into practice (CIDB, 2017; Ghaffarianhoseini, Tookey, Ghaffarianhoseini, Naismith, Azhar, Efinova & Raahemifar, 2017). Although BIM is predominantly enforced by the government, only a few organisations have actually implemented it in their project deliverables. Meanwhile, some organisations opt to outsource their BIM works rather than implementing the technology into their organization itself (Mohd-Nor & Grant, 2014). Numerous research have highlighted the potential benefits of BIM as a supplementary tool to support the industrial evolution, but most of the industry players are not ready to move forward, architects included. Hence, it is essential for further emphasis to be placed in specific areas in ensuring that the industry continuously strives to adopt sustainable and innovative construction methods throughout the value chain. This paper aims to address the issues of BIM adoption by investigating current BIM awareness as well as the state of its adoption from the perspective of an architect.

2. LITERATURE REVIEW

2.1 Overview of Building Information Modelling

BIM is a process involving the coordination of non-digital and digital information about a building project throughout its entire lifecycle (Eastman, Teicholz, Sacks, & Liston, 2011). It collectively involves the elements of efficient workflow, coordination, process, documentation, people, graphical/ non-graphical assets and technology (Eastman et al., 2011; NBS, 2017). The depth of information contained within BIM enables a richer analysis to be obtained in comparison with the conventional processes; it potentially allows the integration of a large quantity of data across several disciplines throughout the building's project lifecycle (Talebi, 2014). BIM brings forward significant influence towards every level of design projects, thus encouraging the construction players to put it into practice. The transition towards BIM is not solely dependent on software and hardware change, the socio-cultural environment is an important factor that provides a significant context for its implementation (Smith & Tardif, 2009; Kensek & Noble, 2014). A successful BIM implementation will firstly require organisations to allocate adequate support to facilitate the expected changes towards organisational work process, policies, people and technological assets within their internal and external environment (NBS, 2017). As the current industry's perception varies across different disciplines, while the levels of expectation increased alongside time, an effective BIM adoption and maximizing its impact render, it is essential to establish the BIM ecosystem within people and organisations (Kensek & Noble, 2014).

2.2 BIM Adoption Issues in the Malaysian Architecture Industry

The local architecture industry has to face numerous issues in attaining successful BIM adoption and emerge progressive, aligning with the construction industry's initiatives and requirements. Several studies have highlighted the low rate of BIM adoption and architect awareness (CIDB, 2017; Mohd-Nor & Grant, 2014). Such considerably low uptake underscores the significance of BIM dissemination within the architectural landscape in understanding its challenges. Currently, BIM adoption is hindered by several factors that is comprised of four core components namely people, process, policy and technology. These factors have been identified as the potential causes of low adoption rate amongst architects (CIDB, 2017; NBS, 2017; Eastman et al., 2012; Smith & Tardif, 2009). In the context of people, the salient factors encountered is the shortage of skilled and knowledgeable BIM workforce in construction organisations (Zahrizan et al., 2014). This is attributable to the difficulties of the learning curve, especially for those completely unfamiliar with BIM, while resistance to its organizational implementation is due to its complexity and high monetary investments required. Inexperienced users may inadvertently change the content of the data, thus imposing risks to a project. In addition, many managers and organisational leaders lack the knowledge on adopting BIM in their respective organisations (Zahrizan et al., 2014). Moreover, the fragmented nature of construction projects contributes towards BIM resistance among the project collaborators (Nanajkar & Gao, 2014). BIM demand changes in an organisation's working 'process' whereby an integrated BIM model development requires efficient communication and greater collaborative efforts across multiple disciplines. Therefore, consented mutual protocols and standard processes are required to initiate responsibility assignment and execute design reviews and validation (Kensek & Noble, 2014). According to Eastman et al., (2011), the standard and guideline are still not well defined in the current practice, organisations remain working in a proprietary format for model exchange. Subsequently, CIDB has raised concerns regarding the need to develop national BIM standards and guideline to manage BIM workflow and adoption (CIDB, 2017), however, many have overlooked the element of construction firm's adoption apart from the sets intended for government projects (Latiffi, Mohd, & Rakiman, 2015).

Furthermore, several technology related issues have been distinguished, such as limited inter-operability between relevant BIM software and the complexities of the software, which lead to ineffective collaboration and workflow (Kensek & Noble, 2014; Memon, Rahman, Memon, & Azman, 2014). BIM technology is often alleged to be costly for implementation and deployment (Eastman et al., 2011; Smith & Tardif, 2009; Memon et al., 2014). Its initiation alone requires a large initial investment of cost to obtain the technology, as well as due to the additional costs of training and development. Meanwhile, Howell and Batcheler (2005) have stated that the difficulties of collaboration are caused by the expectation for the team to inter-operate and adopt single BIM system. This is difficult and limited due to the involvement of a large number of collaborators in a project team. In the context of policy, Eastman et al. (2011) have highlighted legal and contractual problems as one of the challenges for BIM implementation, as the current laws and contracts are ambiguous on BIM matters, including the obligations for the entire BIM project duration. Then, Chien, Wu, & Huang (2014) reports that the legal liabilities and procedures relevant to BIM are unclear in various areas, such as policies, standards contract, ownership of data, insurance, risks and allocation of roles and responsibilities. As the allocation of rights and roles to the project is ambiguous, it is hard to ensure and achieve smooth project progression, thus imposing greater risks to the project.

2.3 Benefits of BIM within the Building Project Lifecycle

BIM application in the construction industry contributes great benefits towards project delivery as it improves the communication between different construction parties, as well as facilitating a faster design decision-making (Cho, Lee, Lee, Lee, Cho, Kim, & Nam, 2011). Figure 1 shows that BIM is capable of project managements at different stages namely Schematic Design, Design Development and Construction Stage (Arayici, Coates, Koskela, Kagioglou, Usher, & O'Reilly, 2011; Azhar, Khalfan & Maqsood, 2015). In order to fully leverage the benefits of BIM, it needs to be implement in all construction stages (Newman, 2013; Weygant, 2011).

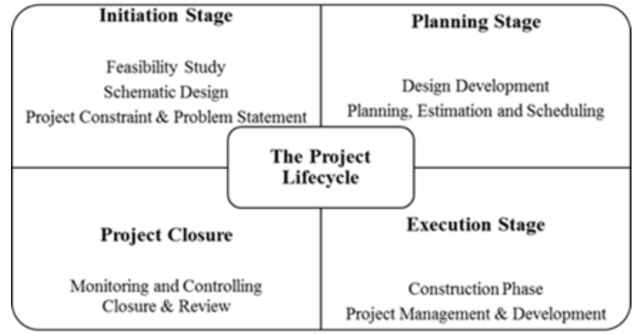

Figure 1: General project life cycle (Watt, Watt, & Adrienne, 2014)

Numerous benefits can be gained by implementing BIM during the pre-design stage, such as early visualisation, preliminary cost estimation, integration with Geographic Information System (GIS) to generate the existing site condition modelling, environmental and building analysis and spatial planning design (Eastman et al., 2011; Arayici et al., 2011; Azhar, Khalfan, & Maqsood, 2015; Abdullah, Sulaiman, Ahmad Latiffi, & David, 2014). BIM is also beneficial in mitigating risks through reviewing the clashes that occurred, highlighting potential errors, conducting a code and compliance review and supporting building component fabrication. (Eastman et al., 2011; Azhar, Khalfan, & Maqsood, 2015). An enriched BIM database will significantly support work processes throughout the whole project lifecycle, which ensures better decision-making, reduction of costs, disputes and time delay; this affirms the quality control, minimized risks of reproduction and reworking of work tasks (Kensek & Noble, 2014). In the recent years, efforts have been made to leverage the potential benefits of BIM in supporting the industry's development. Hence, Table 1 summarize the potential application of BIM in a typical architecture project life cycle ranging from Schematic Design Phase to the Post-Construction Phase.

Table 1: Benefits and Capabilities of BIM

Stages	BIM Capabilities	Sources
Schematic Design Phase (Initiation Stage)	• GIS to analyse, embed and reconstruct the precise existing conditions of a site. • Plan the spatial need and design as defined by the project owner/clients. • Support design communication and ensure better decision-making.	• Dore et al. (2013) • Eastman et al. (2011) • Lahdou & Zetterman (2011)
Design Development Phase (Planning Stage)	• Constructability analysis via clash detection activities during the pre-construction stage. • Extract accurate quantity take-off and estimation. • Environmental analysis such as energy analysis, wind analysis, thermal conditions, solar and lighting study. • Review for compliance with the national building code and regulations.	• Zhang et al. (2016) • Barkokebas, Hamdan, Al-Hussein, & Manrique, (2015) • Eastman et al. (2011) • Lahdou & Zetterman (2011)
Construction Phase (Execution Stage)	• Compute automated construction scheduling, work tasks distribution and duration of activity. • Early identification of design faults via clash detections coordination to reduce risks and ambiguity prior to construction. • Support fabrication and delivery of building components/materials/Industrialised Building System (IBS) • Reduce wastage during construction	• Kim et al. (2013) • Eastman et al. (2011) • Li & Yang (2017) • Lahdou & Zetterman (2011) • Katranuschkov et al. (2013)
Post – Construction (Project Closure)	• The completed BIM model will be occupied by relevant building component information, such as product data and details, operation manual, manufacturer information, contacts and more for scheduled maintenance and effective facility management.	• Katranuschkov et al. (2013) • Eastman et al. (2011)

2.3.1 Quantity Take-off and Cost Estimation

One of the salient use of BIM for construction purposes is regarding its ability to extract accurate material quantity take-off and estimation in order to reduce material wastage, as well as minimise the risks of reproduction. Barkokebas, Hamdan, Al-Hussein, & Manrique, (2015) have demonstrated the application of parametric estimation for a building project, with findings obtained showing a significant reduction of estimated time, change orders and controlled uncertainties, as well as reduction of overall risks associated with the project.

2.3.2 Constructability Detection and Building Analysis

BIM can also be linked with its ability to produce constructability analysis via clash detection activities during the pre-construction stage. Zhang, Long, Lv, & Xiang (2016) observation made using a case study regarding a construction company in China indicates that BIM had solved numerous constructability and reproduction issues happening on-site during the fabrication process. This has been achieved by pre-reviewing the 3D BIM building components in a virtual construction environment. Through clash detection, the manufacturer has also obtained a comprehensive support on the design integration, fabrication, construction, and up to the operation and maintenance processes.

2.3.3 Construction Phasing and Simulation

Kim, Anderson, Lee, & Hildreth. (2013) have stated that one of the important feature of BIM is its ability to compute automated construction scheduling, work tasks distribution, duration of activity based on the production rates and the sequencing rules. These activities can be shared and extracted from an open-data environment using various data exchange formats. The comprehensive 4D BIM data benefits the holistic manufacturing process, which includes material ordering, in-factory logistics, packaging, stocking, and transportation to the construction site. With a streamlined data, a close coordination within the construction value chain is possible and may eventually impact greatly in terms of time and cost (Li & Yang, 2017).

2.3.4 Point Cloud and GIS Integration

The use of Point Cloud Laser Scanning technology and GIS allows, designers to analyse, embed, and reconstruct the precise existing conditions of a site. Utilising both technologies greatly benefits the designers in obtaining accurate data during the initiation of the preliminary design. Point cloud utilisation alone enables precise documentation of buildings for refurbishment and conservation works. In a study by Dore & Murphy (2012), a Heritage-BIM documentation approach has been demonstrated involving a 3D modelling stage. The 3D model integration into a 3D GIS has allowed further building documentation management and analysis.

2.3.5 Code and Compliance Review

BIM is an important digital assets in communicating design, and it is a key instrument in reviewing and obtaining the approval from statutory bodies. BIM model may be authorised for conducting plan review and ensuring conformance for the building code (Eastman et al., 2011), as the approaches to develop an automated code-review have been studied in past research (Eastman et al., 2011; Greenwood, Lockley, Malsane, & Matthews (2010). Several countries like Singapore and Australia have proceeded to implement online-based E-Submission platform compliance to code and building plan approval, namely Construction and Real Estate Network (CORENET) and DesignCheck, respectively.

3. RESEARCH METHODOLOGY

3.1 Research Approach

Quantitative research is defined as a proper, methodical, and objective-based process of obtaining data by applying numerical data retrieved from a sample of population such as by using surveys. The advantage of applying the approach to this study was that it enabled the study of trends, attitudes, or opinions of a population which in this case referred to the architecture industry (Creswell & Creswell, 2013). Survey questionnaire was chosen as the method of collecting data as the approach was deemed effective in collecting objective-based and measurable data required for this research (Kumar, 2014). The questionnaire's format consisted of four (4) sections containing mostly close-ended questions. The first section (1) aimed to identify the respondent's profile and details of their participation in BIM. Then, Section Two (2) elicited the benefits of BIM implementation and, Section Three (3), the barriers and drivers of BIM. Lastly for Section Four (4) incorporated an open-ended question to extract the respondents' personal opinions and comments on the context of research. Prior to the actual data collection process, a preliminary survey was conducted with the participation of experienced academicians, professional architects and BIM professionals so as to obtain preliminary content validity for the questionnaires.

3.2 Sampling Method

Random sampling method was used to determine the sample size for this study as it was appropriate to be applied for a preliminary study in which a complete list of the population was available (Kumar, 2014). A total of 322 survey questionnaires were sent out in a period of one (1) month to respondents who are working as an architect either on the behalf of architecture firms, clients, or BIM consultants within all states of Malaysia. The population sample size was drawn from the current registrants of Malaysia Board of Architects (LAM), whereby, there are currently 2,250 Professional Architects (Ar.) and 2428 Graduate Architects (GA) registered. Thus based on the study by Krejcie and Morgan (1970), a sample size of 354 respondents was suitable for this research in which the potential respondents were preferably architects with experience in BIM projects. Out of the 354 questionnaires distributed, 108 questionnaires were completed and returned, with a representation of 31%. The response rate was similar with previous construction studies conducted by Newton & Chileshe (2012) and Jin, Li, Zhou, Wanatowski, & Piroozfar (2017), which obtained 39% and 13%, respectively.

3.3 Statistical Approach

The study used the descriptive statistic approach to analyse the data collected using specific analysis techniques, such as frequency distributions and ranking analysis (Ary, Jacobs, Sorensen & Razavieh, 2010). The use of frequency analysis was critically required to support other statistical methods, as detailed by Kumar, (2014). The data collected from the survey were inserted and analysed using IBM SPSS software. Furthermore, ensuring the responses obtained from the questionnaires were transformed into accurate and meaningful data resulted in the analysis being undertaken using various data analysis tools. They included the mean rating (MR) and standard deviations (SD); they are regarded as the most significant method to calculate the central tendencies in representing the average group of data for a variable (Ary et al., 2010). The MR, in particular, indicated the relative magnitude of variables in areas concerning the research objectives, namely the level of importance, awareness and agreement.

3.4 Demographic Profile

Table 2 shows a total of 108 respondents who participated in the survey, whereby a majority of them were categorised into managerial and operational groups, namely Graduate Architects (41.7%), Senior Architects (30.6%), Principal (9.3%) and Associates/Directors (7.4%). Most of the respondents' possessed more than 5 years of working experience (70%), thus indicating a high level of confidence in responses based on their involvement in design projects. Furthermore, 49 respondents (45.4%) representing different companies did not use BIM within their practice, while 12 respondents (11.1%) showed fresh involvement in BIM implementation with less than a year of experience. Then 40 respondents (37%) had moderate experience between 1 to 5 years with BIM while only 7 respondents (6.5%) possessed more than 5 years of BIM experience. The high percentage of non-BIM usage indicated that the level of BIM adoption within the industry is still at an infancy stage, thus underlining the need to further analyse the impact factors of its BIM adoption. The study also compared the senior and junior role groups (i.e. Senior Group consisting of Senior Architects, Associates, and Principal; and Junior Group consisting of Assistant Architects and Graduate Architects) from the survey to assess the presence of any non-response bias in the data (Churchill & Iacobucci, 2009). Hence, an independent t-test was executed and the results did not show any statistically significant difference of opinions between both groups.

Table 2 : Respondent's Demographic Profile

		Frequency (N)	Percentage (%)
Role of Respondents	Principal	10	9.30%
	Associate/ Director	7	6.50%
	Senior Architect	32	29.60%
	Graduate Architect	45	41.70%
	BIM Executive	2	1.90%
	Assistant Architect	12	11.10%
	Total	108	100.00%
Work Experience	Less than 5 years	41	38.0%
	5 to 10 years	48	44.0%
	More than 10 years	19	18.0%
	Total	108	100.00%
BIM Working Experience	Less than 2 years	40	37.0%
	2 to 5 years	12	11.1%
	More than 5 years	7	6.5%
	None	49	45.4%
	Total	108	100.00%
Age Group	Above 40 years old	9	8.3%
	30 – 40 years old	60	55.6%
	Below 30 years old	39	36.1%
	Total	108	100.00%

4. RESULTS

4.1 BIM Adoption within the Architecture Industry

Table 3 shows that a majority of the respondents at 45.4% had no BIM working experience, while the second highest group of 37% had less than 2 years. This was followed by 2 to 5 years (11.1%) of experience, while the remaining 6.5% of the lowest group had more than 5 years of BIM experience. Although the majority group lacked BIM experience, they remained to relatively aware of BIM. Only one (1) person declared to be unfamiliar with BIM. Overall, this indicated that the level of BIM usage was still at a low level, and the trend of BIM was comparatively fresh in the industry.

Table 3 : Cross-tabulation between respondent's BIM experience and awareness of BIM

BIM Working Experience		**Are you aware of BIM**			**Total**
		Yes	**Moderate**	**No**	
Below 2 years	Count	34	6	0	40
	% of Total	38.20%	33.30%	0.00%	37.00%
2 - 5 years	Count	12	0	0	12
	% of Total	13.50%	0.00%	0.00%	11.10%
Above 5 years	Count	7	0	0	7
	% of Total	7.90%	0.00%	0.00%	6.50%
None	Count	36	12	1	49
	% of Total	40.40%	66.70%	100%	45.40%
Total	Count	89	18	1	108
	% of Total	82.40%	16.70%	0.90%	100.00%

Table 4 shows the current BIM usage that is different according to the size of the firms. The responses to this question showed that the percentage of BIM users among the larger firms was higher (53%) than the medium firms (31%) and smaller firms (16%), accordingly this results was consistent with BIM reports conducted in the United Kingdom (UK) and Australia, whereby such trend strengthened the claim that larger firms were more capable and willing to invest in BIM technology (NBS, 2017; Rodgers, 2015). Meanwhile, most of the small to medium firms did not use BIM in their practice (54.6%). As highlighted in Construction (2014), large firms had an added advantage to adopt BIM due to the high level of resources and expertise they possessed. In contrast, projects delivered by Small and Medium-Sized Enterprise (SME) firms might take better advantage of BIM than large-sized projects (Arayici, 2014).

4.2 BIM Benefits and Capabilities from the Architect's Perspectives

The research further studied the level of BIM awareness from the perspective of an architect, whereby the Cronbach's alpha obtained for the set of inventory scale was highly reliable (α=0.91). Furthermore, the variables obtained from the secondary data were grouped into three (3) main stages of design project namely the Schematic Design (SD), Design Development (DD), and Construction Stage (CS). The respondents were required to rate the scale of importance from '5' as the most important to '1' as the least important. The results are shown in Table 5 below.

Table 4: Company Size and BIM Usage

Company Size	BIM Usage in Firm		
	Yes	No	Outsourced
Below 10 person	8	21	1
10 - 30 person	13	22	4
30 - 50 person	2	1	0
Above 50 person	26	8	2
Total	49	52	7

Overall, the design development stage (DD) displayed the highest degree of importance compared to other stages. Ranked as first, the majority of respondents highly agreed that the most important BIM benefits was its ability to produce integrated 2D and 3D drawings (M: 4.46, SD: 0.79). Secondly, the respondents were highly aware that apart from the production tools, it also provided an information platform for better communication within the project team (M: 4.43, SD: 0.776). They also highly agreed that BIM required a high level of involvement between the stakeholders in a project team (M: 4.43, SD: 0.751). Meanwhile, in the context of the schematic stage, the respondents were highly aware that BIM model could be utilised to detect any design clashes between relevant disciplines (M: 4.35, SD: 0.91), as well as to conduct complex building structural analysis (M: 4.28, SD: 0.818). The areas with the least degree of importance were identified as 1) the use of BIM for code and compliance review (M: 3.29, SD: 1.231), 2) the use of point cloud and laser scanning to produce accurate existing site condition modelling (M: 3.18, SD: 1.303) and 3) the integration of BIM and GIS to produce accurate physical and non-physical representations of the site conditions (M: 3.06, SD: 1.334). The architect's awareness placed more emphasis on the benefits within the schematic and design development. Additionally, the construction stage (CS) displayed the most consistency of somewhat to moderate awareness, whereas all of its variables were within the intermediate ranking of 12 to 18 and most were below M: 4.00.

Table 5: Benefits of BIM Implementation

Stages	BIM Benefits and Capabilities	Mean (M)	Std. Deviation (SD)	Rank
SD	High level of collaboration in a project team.	4.43	0.751	3
SD	BIM is able to provide early and accurate visualisation.	4.12	0.862	6
SD	Improved delivery throughout all project lifecycles.	4.08	0.887	7
SD	BIM is able to plan spatial needs as defined by owners.	3.86	0.961	10
SD	BIM is able to generate conceptual massing.	3.83	1.18	11
SD	Point cloud technology for existing condition modelling.	3.18	1.303	20
SD	Integration of GIS with BIM.	3.06	1.334	21
DD	2D to 3D drawing production.	4.46	0.79	1
DD	Information platform for better communicaton.	4.43	0.776	2
DD	Detect clashes between various diciplines.	4.35	0.91	4
DD	Conduct complex structural analysis.	4.28	0.818	5
DD	High degree of realism.	3.99	0.891	8
DD	Conduct simulation / immersive virtual lab.	3.94	1.061	9
DD	Digital record storing (Common Data Environment).	3.83	1.00	11
DD	Producing cost estimates and quantity takeoff.	3.65	1.122	14
DD	Environmetal simulation and analysis.	3.56	1.154	16
DD	Code and compliance review.	3.29	1.231	19
CS	Early identification of design constraints.	3.80	1.066	12
CS	Reduce construction wastage.	3.74	1.08	13
CS	Reduced 'Request for Information' (RFI) and variation order in construction.	3.64	1.18	15
CS	Comprehensive data on provider and product detail.	3.56	1.178	16
CS	Support fabrication of building components.	3.54	1.089	17
CS	4D BIM - construction phasing and simulation.	3.40	1.215	18

4.3 BIM Readiness and Driving Factors

BIM organisational readiness can be expressed as the level of preparation, participation and capability to innovate (Succar & Kassem, 2015). The study further investigates the tendency of an organisation to adopt BIM. Figure 2 shows that the majority of organisations were generally positive towards adopting BIM as 59.8% of them were currently investing in BIM training and development within their organization. Meanwhile, 66.2% had shown their readiness to adopt BIM by investing in BIM software and hardware. All respondents also revealed significant confidence for BIM to further impact the future of construction project management, with 96.3% representation.

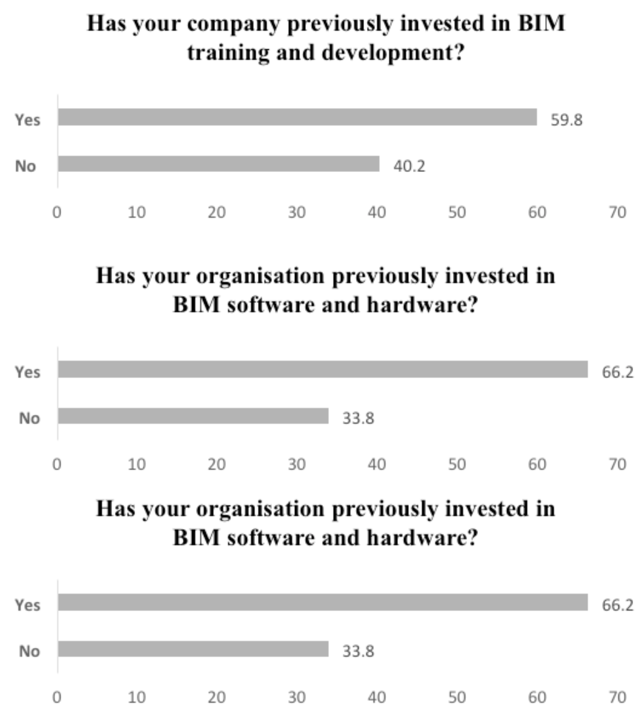

Figure 2 : Company Readiness to Implement BIM

The survey further identified the most impactful BIM improvements. As shown in Table 6, the scope was narrowed to the most salient driving factors for pushing BIM adoption as perceived by Malaysian architects. Based on the findings obtained from the secondary data, a total of 20 variables were categorised under four BIM components (ie. people, process, technology, and policy) and consequently 14 salient driving factors were identified for the research. The people factors revealed the most consistency of agreements, whereby the majority agreed that increasing the pace for BIM required gaining the support from professional bodies like Malaysia Board of Architects (LAM) and Malaysian Institute of Architects (PAM), (M: 4.51, SD: 0.74). Another important driver was enhancing BIM education and awareness within the architecture profession, with an overall mean of 4.48 (SD: 0.767). The third driver called for further involvement and cooperation from the governmental bodies in providing support, as well as in enforcing BIM utilisation in design projects (M: 4.43, SD: 0.726). The findings were in line with several past studies that highlighted the enforcement of BIM by the government that would help and enhance BIM practices in construction projects (Latiffi et al., 2015). Furthermore, all respondents agreed for the need of public and private bodies to conduct in-depth BIM research and development (M: 4.43, SD: 0.700). Moreover, BIM enforcement by clients was another important aspect in spearheading its implementation (M: 4.40, SD: 0.785). In addition, all respondents agreed that the investment and support from the organisational leader were important to drive the process of BIM adoption by companies (M: 4.38, SD: 0.817). Apart from that, a BIM standard and guideline (M: 4.30; SD: 0.788) should be developed to further support the change of processes in an organization for adopting BIM. In the context of policy, the respondents' agreed regarding the need to establish relevant policies and incentives to promote BIM (M: 4.34, SD: 0.738), as well as developing a standard legal or contractual agreement relating to BIM (M: 4.25, SD: 0.822). Several technology factors were also identified especially to address the technical complexity of BIM such as to standardize the open BIM standard for efficient inter-operability (M: 4.31; SD: 0.719) and to establish a BIM technical group to resolve any BIM complexities (M: 4.29, SD: 0.786).

Table 6 : Driving Factors of BIM Adoption

Factors	Driving Factors of BIM	Mean (M)	Standard Deviation (SD)	Rank
Technology	Technical progress in computing and IT technologies.	4.26	0.836	11
People	Enhancing BIM education and certifications.	4.48	0.767	2
Policy	Establish policies and incentives to promote BIM.	4.34	0.738	7
People	Support from architecture professional bodies (LAM, PAM).	4.51	0.704	1
People	R&D collaboration with universities to enhance BIM education.	4.43	0.700	4
Policy	Development of BIM standard legal or contractual agreement.	4.25	0.822	12
People	Demand of BIM from clients.	4.40	0.785	5
People	BIM enforcement by government / local authorities.	4.43	0.726	3
Process	Specialisation of design services towards BIM.	4.23	0.860	13
Technology	Grant subsidies and provide affordable BIM.	4.25	0.822	12
Process	Support for BIM from top management of organisation.	4.38	0.817	6
Process	Develop complete BIM standard and guideline for organisations to adopt.	4.30	0.788	9
Technology	Establish BIM technical group to solve technical / complexity issues.	4.29	0.786	10
Technology	Standardise open BIM file format for inter-operability.	4.31	0.719	8

5. DISCUSSIONS

5.1 BIM Usage and Awareness from the Architect's Perspectives

Overall, the results show positive signs of BIM awareness by architects, as more than 80% of the respondents were generally aware of BIM and its capabilities. However, the level of BIM usage was still low as only 17.6% of the architects had more than 2 years of experience working with BIM. The rate was significantly increased from the previous study conducted, whereby less than 50% of the construction players were aware of BIM (CIDB, 2017). The results also show that 45.4% of the firms had the tendency to adopt BIM into practice, but the amount of BIM projects executed by these firms was still low at the capacity of below 20%. This clearly indicates that the BIM trend by organisation was still at the embracement stage, which was similarly faced by the overall construction industry (CIDB, 2017; Mohd-Nor & Grant, 2014). Furthermore, the findings identified the larger firms to be relatively more prone towards using BIM as compared to SME firms. Therefore, it is important to further study the impact of BIM to these SME firms, as the projects delivered by SME firms might take advantage of BIM as compared to large scale projects (CREAM, 2014; Arayici et al., 2011). Besides, a majority of the respondents were collectively aware regarding the concept and the technical aspects of BIM. In the schematic design stage, key findings show that most respondents scored the lowest mean values on the technical aspects, such as the use of point cloud and 3D laser scanning technology, supporting existing condition modelling, and the integration of BIM and GIS technology. In many instances, the benefits of GIS especially in design and planning organisations were perceived by an individual as a threat and an opportunity to others (Hussain, 2011). Thus there is a need to provide exposure to the architects in leveraging the potential benefits of GIS integration in design (Azhar et al., 2015). In the design development stage, the least known factors were the use of BIM to conduct environmental simulation and analysis and for code and compliance review. In comparison to the traditional approach, the code and compliance process with BIM could motivate users to adopt BIM at an earlier stage (Martins & Abrantes 2010). Lastly, in the construction stage, the architects possessed the least awareness of BIM in the approach to support the fabrication of building components and 4D BIM construction phasing and simulation. BIM has the ability to produce construction simulation in order to mitigate risks, reduce wastage, and enhance the health and safety for construction (Eadie, Odeyinka, Browne, McKeown, & Yohanis, 2013), highlighting the benefits of its implementation in the context of architecture. In specific, the variables that revealed the least awareness overall were the use of BIM for building code and compliance review, point cloud and laser scanning that enabled the generation of 3D BIM existing condition, and the potential integration of BIM with GIS. Therefore, there is a need for further study to establish its potential usage and application.

5.2 BIM Readiness and Driving Factors from the Architect's Perspectives

The study further observed organisation readiness to adopt BIM, whereby it is interestingly to note that over 60% of the architecture firms started to initiate their financial investment in preparing their internal assets and manpower towards BIM. This is a significant improvement from the previous national BIM report that reported over 60% of companies within the industry were unwilling to allocate any financial incentives or support to use BIM, as well as invest in BIM trainings and assets (CIDB, 2017). As the implementation of BIM requires change to the organisational values and culture, the findings clearly show positive signs of future BIM adoption within the industry. The study further identified the salient driving factors to be imposed for propelling BIM forward in the architectural landscape. The people factor had the highest consistencies of agreement, whereby among the key highlights is the increased demand for the government, education sector, and support of architectural professional bodies to play a leading role and support the development of BIM adoption within the industry. This has been highlighted by Kushwaha (2016) and Eadie et al. (2013), claiming the lack of initiative from the government, professional organisations, and educational institutes as the major factor attributable for the limited awareness and implementation of BIM. Therefore, governmental and professional bodies (e.g. PAM and LAM) may organise a series of awareness and motivation programmes, such as seminars and workshops for architecture professionals and students. In addition, CIDB has been proactively taking the lead in BIM development with the establishment of MyBIM centre to facilitate trainings and seminars on BIM adoption (CIDB, 2017). Apart from that, enforcement is a key step to drive the use of BIM. Singapore, as an example, has enforced the practice of code checking and building plan e-submission for its local authorities through CORENET (Construction and Real Estate NETwork). With regard to the education aspect, numerous research have highlighted the importance of having a structured BIM courses at the level of tertiary education (Rogers, Chong, & Preece, 2015; Haron, Soh, Ana, & Harun, 2017). Institutions of higher learning throughout Malaysia are encouraged to incorporate BIM courses in their syllabus to allow their graduates to understand BIM technology as a preparation to meet the challenging demands of the industry. In addition, the trend of low BIM usage by architects can be changed through the role and influence of clients. Several studies have revealed that the adoption rate by clients or developers is at the lowest amongst the construction players. The lack of demand is due to the reluctance to change, fear of increased cost, and lack of knowledge and awareness on BIM (CIDB, 2017; Memon et al., 2014). Such lack of demand would ultimately hinder BIM adoption as it is vital for clients to increase their involvement in order to realise a sustainable construction industry (Memon et al., 2014). Meanwhile, BIM requires significant procedural and technological changes in an organisation (Araiyici et al., 2011). Hence, adapting such processes rendered the respondents' collective agreement for the organisational leaders to play an important role towards the transition. Currently, no effective standard and guideline has been developed specifically for BIM adoption by organisations (Zahrizan et al., 2013). Further risks may emerge should organisations develop their own BIM standards and protocol, causing unclear collaborative procedures between the project teams. In the technology context, findings from the secondary data revealed that several BIM limitations experienced by construction organisations included issues like interoperability, complexity of software, requirement of enhanced collaboration and requirement of coordinated drawing (Memon et al., 2014; Kensek & Noble, 2014; Howell & Batcheler, 2005). In addressing these technological obstacles, the respondents collectively agreed regarding the need to develop an open-BIM standard for interoperability. This can be addressed by establishing a dedicated technical group to resolve any technical complexities or issues that arise from BIM usage. Moreover, its implementation is costly as it demands copious amount of investment to transform the work process and flow of an organisation. Thus, the provision of grants and subsidies to attain BIM was highlighted by the respondents to promote the use of BIM technology.

6. CONCLUSION

Despite the rapid development to harness the benefits of BIM as a means of sustainable project delivery in the construction industry, the current adoption rate by Malaysian architects were still low with the majority of firms remained in a preliminary state. Most of the architects are aware of BIM and its capabilities, with the majority demonstrating a somewhat moderate level of awareness. Furthermore, the research identified the current level of awareness according to the stages of building project, whereby the findings showed that the construction stage had the most consistency of low awareness level as compared to other project stages. In specific, the benefit that displayed the lowest level of awareness was the potential of adoption between BIM with GIS, as well as for building code compliance and review. In contradictory with previous studies in the construction industry, most of the architects believed that BIM would impact the future of design project management and subsequently initiate their commitment towards adopting BIM. Several driving factors were also determined by the respondents to improve the use of BIM in the industry. The low BIM uptake revealed, underscores the significance of BIM diffusion within architectural organisations to further understand the barriers and drivers of BIM adoption. Consequently, this study provided further insight and findings regarding the adoption of BIM, which serves as a critical reference point for local architects to assess the changes and effects that are crucial in determining the progress of BIM in Malaysia. Finally, several limitations need to be acknowledged, specifically, time constraint and relatively small sample sizes, which may lead to concerns on generalisation of the research findings.

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