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THE ADOPTION OF BUILDING INFORMATION MODELLING (BIM) USES IN THE CONSTRUCTION PHASE FOR BIM BASED PROJECTS: THE CONTRACTORS' PERSPECTIVE

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Abstract

Of-late, the trend of digitalization, automation and the use of Information and Communications Technology (ICT) in the Construction industry which encompasses Internet of Things (IoT) and cloud computing are defined as the Fourth Industrial Revolution 4.0 (IR 4.0). Thus, as IR4.0 introduces digital technology, Building Information Modelling (BIM) has become the main accelerator in producing digital information for construction projects. Through BIM, the construction information is stored, supplied and received in one single respiratory system which enables the BIM-based project team to interact and collaborate in real-time throughout the project life cycle. Nevertheless, the adoption of BIM in the Malaysian Construction Industry and particularly for contractors are relatively low. This is because contractors have no profound understanding of BIM and its requirements. Hence, this study aims to determine the significant uses of BIM from the contractor's perspective which covers six (6) uses during the construction phase. To do so, a cross-sectional survey was conducted inside the Malaysian Construction Industry particularly for BIM-based project contractors. As a result, the 3D coordination and the record model remarked the top significant uses in the construction phase. This shows that the uses of BIM are to minimize the discrepancy of drawings and visualizations and to create a record model for facility management purposes. Thus, the results of the study also provide insight to the project teams especially contractors, clients, consultants and other stakeholders take into consideration the uses of BIM for future BIM-based projects.

Keywords: *building information modelling (BIM), adoption, uses of BIM, contractor, BIM-based projects*

1.0 INTRODUCTION

Industrial Revolution 4.0 (IR4.0) has become the catchphrase of the day. It is defined as a cyber-physical system (CPS), Internet of Things (IoT), big data, smart production and artificial intelligence (AI) which is useful as a modus operandi in the construction industry (Maskuriy et al., 2019). It is also recognized as a 'digital revolution' as the transition from mechanical devices, analogue electronics to digital technology (Rojko, 2017; Alaloul et al., 2018 ; Othman et al., 2020). With the connection of technology and people, IR4.0 aims to become viable and sustainable in the manufacturing sector which allows the integration of the technical and business process and thus allows smart factories. As the concept of IR4.0 emphasizes in the construction industry, the Malaysian Government has conscripted the National agendas such as the "Construction Industry Transformation Programme" (CITP) by the Construction Industry Development Board (CIDB) (2016-2020) in 2015. Several initiatives and activities are conscripted as an act of awareness for the construction industry to embrace IR4.0. Consequently, the Building Information Modelling (BIM) is one of the initiatives in CITP which is emphasized under thrust 3 (productivity). The leveraging of BIM adoption by CIDB is to promote efficiency in the construction methodology as well as to support IR4.0 (CIDB, 2016b); (CIDB, 2019).

The Building Information Modelling (BIM) is defined as having an IT-enabled approach which involves the integral digital representation of all building information in the form of repository for various phases of the projects lifecycle (Gu & London, 2010). It is also defined as a process to produce, communicate and analyse digital information throughout the construction life-cycle in the form of 3D modelling (CIDB, 2014). Apart from this, BIM with the processing and integrated tools of the project data that reshape the way of the construction team to work together in order to achieve the ultimate project outcome (i.e., time, cost, quality and safety) (Rohena, 2011; Hadzaman et al., 2015) (If first time mentioned, include all authors). . Despite the advantages of BIM, the adoption of BIM among contractors is reported to be low as compared to other stakeholders in Malaysia. This is shown in BIM reports as produced by the Construction Industry Development Board of Malaysia, (CIDB, 2016a) which revealed that contractors have the lowest adoption rate which is 13%, while architects have the highest adoption rate which is 42% and followed by engineers (21%) (CIDB, 2016a). This percentage also remains stagnant as Idrus and Bahar (2018) reported that the level of adoption of BIM by contractors is still less than 20%. According to George (2015), many stakeholders especially contractors do not have a profound understanding of what BIM is and also its requirements. Added to that, the contractors have not taken note of the abilities and benefits offered by BIM. Furthermore, it is also perceived to be expensive to many stakeholders and a high difficulty rate in using it with an uncertain outcome (Khosrowshahi & Arayici, 2012). Hence, due to that reason, the adoption among the contractors became slow. Furthermore, the project outcome such as cost, time, quality and safety also depends on the uses of BIM which involve contractors. Clear BIM uses determined during the early phases will aid the contractors to reap the benefits of BIM. Hence, the objectives of this paper is to determine the significance of BIM uses towards the contractors perspective by adopting BIM during the construction phases.

2.0 BIM USES IN BIM-BASED PROJECTS

According to the Computer Integrated Construction Research Program, (2010) and Group Computer Integrated Construction Research (2019), BIM use is defined as a method applied in any BIM-based projects to achieve specific objectives. It is also defined as a BIM service and function which consists of tasks and procedures to support the project's planning, design, construction, and operational processes (Won & Lee, 2016). In addition to that, the Computer Integrated Construction Research Program (2010) and Computer Integrated Construction Research (2019) listed twenty-five (25) uses of BIM across the project life cycle (planning to operation and maintenance).

Nevertheless, due to the scope of contractors in this study that are involved in the construction phase, BIM uses that are from the Planning, design and operation and maintenance phases are excluded. As a result, six (6) uses of BIM are described as follows:

a)	3D Coodination	:	Process to provide coordination between trades such as architectural, structural, and MEP models in a project by way of clash detection (Chou & Chen, 2017).
b)	Site utilising plannin	:	BIM model serves a graphic representation for permanent and temporary facilities on-site during multiphases of the construction phase such as labour resources, materials and equipment location.
c)	Construction system design	:	Use of 3D design software to design and create virtual mock-ups of building systems such as formwork systems, glass veneers, and anchor systems (Chou & Chen, 2017).
d)	Digital fabrication	:	The digital information used to facilitate the fabrication of construction materials and assemblies
e)	3D control and planning	:	The process by using the digital information model to layout facility assemblies or automate control of equipment’s movement and location.
f)	Record model	:	The process to record the information related from the architectural, structural and MEP elements in order to provide record data for facility managers or owners during the operational and maintenance phase

As BIM-based project contractors, they are required to choose the most reasonable and achievable uses of BIM in respective to each project, as a goal for the early stages of a project

(Chou & Chen, 2017). This is because it will affect the selection of software, hardware, team expertise and processes. Moreover, the right BIM goals and uses of BIM will help to achieve the targeted project performance which can reduce the project duration, project cost saving and increase the project quality (Ibrahim, 2018).

3.0 METHODOLOGY

The empirical test of this study was conducted using the survey technique. A developed item- questions from questionnaire surveys were reviewed for content validity throughout five (5) BIM specialists, two (2) BIM-based project contractors and ten (10) academicians from similar and different fields of study including the statistical department. The questionnaires were sent to the contractor's office from June until September 2018. For the first three (3) months, postage was used while self-distribution of questionnaire surveys was carried out for the next one (1) month. In total, 114 questionnaires were completed and returned which represented a response rate of 33.53% (as per table 1) and is acceptable in the construction research as suggested by Fellows and Liu (2003). Respondents within the organisations who have experience in BIM-based projects with different designations were selected such as CAD/managers, Project managers, BIM modellers, Project engineers, Estimators Principals/Directors/VPs (Top management) and others. The various types of designations were as recommended by Mutai (2009) and Monko et al. (2017) in order to give various results.

Table 1: Acquisition of questionnaires data

No	Distribution	Total	Percentage (%)
1	Questionnaires distribution	340	
2	Questionnaires received	129	37.94%
3	Unusable questionnaires	15	4.41%
4	Usable questionnaires	114	33.53%
	Overall response rate	**33.53%**	

In this study, a seven-point Likert scale was deployed to the respondents to indicate their level of agreement and disagreement which starts from "never used" to "always used". The purpose of this Likert scale is to gather the information for this study and later to be analysed using the *Statistical Package of Social Science 23.0 (SPSS 23.0).*

4.0 FINDINGS AND DISCUSSION

The findings and discussion of the respondent'sprofile and statistical analysis (descriptive and inferential analysis) are presented in this section.

4.1 Respondent's Profile

Figure 1 – 3 shows the demographic background of the respondents. The participants come from various backgrounds, positions (professions) and experience in construction as well as BIM. As a result, from figure 1, it indicates that most of the respondents are contractors (71%), followed by BIM consultants (19%) and consultants (10%). This implies that BIM-based project contractors are involved in various project delivery methods either it is design-bid-build, design and builds or integrated project delivery. Therefore the involvement of consultants and BIM consultants is vital. Besides, the BIM consultant is appointed by the contractor to assist the contractors during the adoption of BIM in their projects (Zakaria et al., 2013): (Ibrahim, 2018).

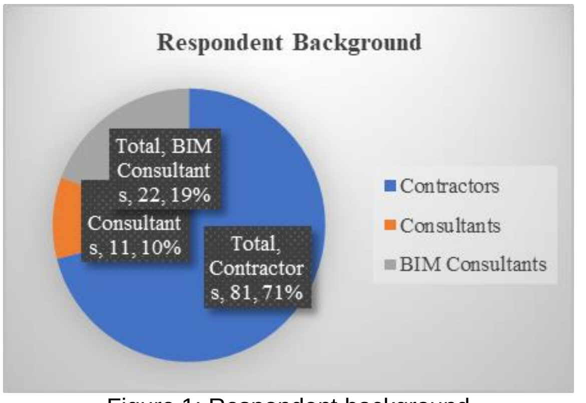

Figure 1: Respondent background

In terms of the experience in the construction industry (as figure 2), the respondents have various periods of experience in BIM-based projects in which the minimum experience is less than 5 years (31.6%), 6-10 years (26.3%), 11-20 years (33.3%) and above 20 years (8.8%). This shows that the respondents with 10 years experience are the highest in this discussion. It implies that these respondents know the scenario of the construction industry. Surprisingly, the respondents who are beginners are also among the highest number of respondents in this study. This is because the adoption of BIM among BIM-based projects in Malaysia is still in the infancy stage. Therefore, these groups have great knowledge of BIM compared to the respondents which have more than 20 years experience. Hence, as the nature of this study is to gain BIM knowledge from experienced respondents, the respondents with more than 20 years experience in the construction industry with zero knowledge of BIM are excluded in this study. With various types of working experience in the construction industry, their participation provides a rich and reliable value to the study.

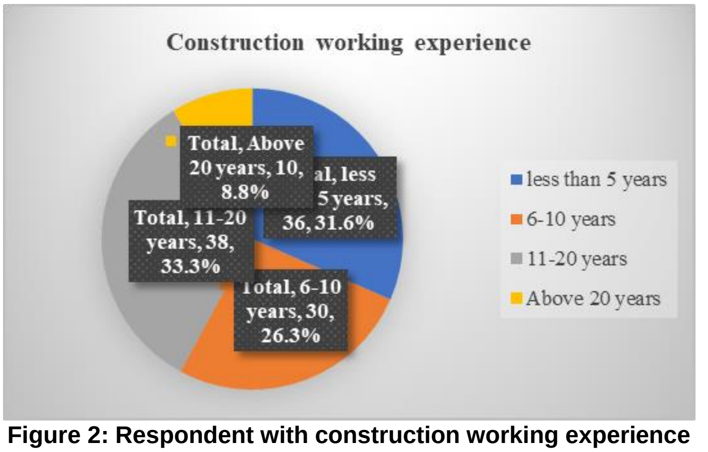

Figure 2: Respondent with construction working experience

As mentioned earlier, the respondents with BIM working experience are accepted in this study. Thus, as a result, 35.1% of the respondents have more than 5 years of experience in BIM, 34.2% of respondents have been involved in 3-4 years and 30.7% of respondents have less than 2 years experience in BIM. This shows that the respondents that have at least five (5) years of BIM experience are familiar with the issues that occur as well as an understanding on the BIM concept (Ku & Taiebat, 2011); (Ibrahim, 2018). Consequently, it can be deduced that the selection of respondents are appropriate and suitable as they can provide related issues on BIM as well as the current scenario in the construction industry.

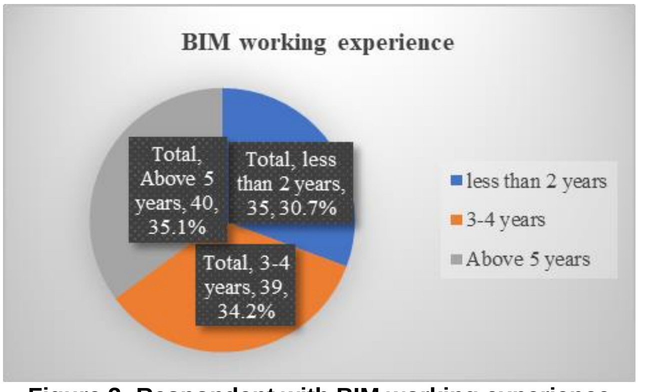

Figure 3: Respondent with BIM working experience

4.2 Statistical analysis

As mentioned earlier at 3.0, the results by means of means index, standard deviation, ranking and t-test were analysed and obtained from using the *Statistical Package of Social Science 23.0 (SPSS 23.0).* The descriptive analysis which consists of mean and inferential analysis such as t-test are ranked from the highest mean index to the lowest mean index. As such, table 2 presents six (6) uses of BIM in the construction phase. '3D coordination' presents the most significant use (mean=5.8070, SD=0.76282), followed by 'record model' (mean=4.9912, SD=1.00877), and 'construction system design' (mean=4.8070, SD=0.93010). Subsequently, fourth place until six places are listed as frequent uses of BIM such as '3D control and planning' (mean=4.6140, SD=1.15604), "site utilising planning' (mean=4.5789, SD=1.088110 and finally 'digital fabrication' (mean=4.3246, SD=1.14053).

Table 2: Uses of BIM in construction phase

Uses of BIM	Mean score	Standard deviation	Ranking	T-test
3D Coordination	5.8070	.76282	1	32.291
Record model	4.9912	1.00877	2	15.784
Construction system design	4.8070	.93010	3	15.004
3D control and planning	4.6140	1.15604	4	10.289
Site utilising planning	4.5789	1.08811	5	10.587
Digital fabrication	4.3246	1.14053	6	7.719

Meanwhile, based on Table 2,a sample t-test was conducted by taking a 95 percent significance level with a test value of 3.50 (Seyedin et al., 2011): (Ismail, 2016) in order to determine the demarcation for the items. From the results, it shows that the items perceived by the respondents significantly affect the BIM-based project contractors. It also indicates that all the items in table 2 have a higher significant level than 3.50. Hence, all these items are statistically relevant concerning the uses of BIM in the construction phase by BIM-based project contractors.

The consistency of the results from both analysis (mean index and t-test) shows that 3D coordination is the highest ranking in the uses of BIM in the construction phase. This is supported by various researchers, such as Hanna et al. (2013); Kent (2014); Guo, et al. (2014); Kent, Miller, & Farnsworth (2017), that revealed 3D coordination to be the highest use among commercial MEP contractors. Furthermore, Hussain & Choudhry (2013); Jung & Lee (2015); Won & Lee (2016): (Chong et al., 2016); (Chou & Chen, 2017): (Franz & Messner, 2019) also revealed that 3D coordination is the top use among BIM-based projects in North America, Europe, Oceania, Asia, Middle East and Africa and South America. Besides, this is also in line with Ibrahim (2018) which found that 3D coordination in the form of clash detection is the utmost used among construction players for BIM projects in Malaysia. Through this process, all the drawings are combined in the form of federated models by using BIM platforms such as Naviswork to perform clash detection. Hence, the conflicts (either hard clash and soft clash) can be resolved before the construction starts and reduces the number of requests of information due to design changes and rework on the site (Sacks et al.,2018). In addition, this

3D coordination is also used to avoid conflicts in construction projects as well as to reduce cost and increase the quality of models.

The second in rank is the record model. This recording model involves the depiction of the information related to architectural, structural and Mechanical Electrical and Plumbing (MEP) elements and is documented in the form of the model (Computer Integrated Construction Research Program, (2010): Computer Integrated Construction Research, (2019). The final model consists of information of each object property that includes links to submittals, warranty information, operations and maintenance information (Hergunsel, 2011); (Azhar et al., 2012). This single source of dabase facilitates facility management to manage and find the information later and is applied to various scopes of operation and maintenance.

Subsequently, the third to the sixth place of the significant uses of BIM are construction system design, 3D control and planning, site utilising planning and digital fabrication. Hence, it shows that 3D control and planning can be used to assemble and manage the movement of the equipment and the accurate position or layout such as layouts of walls using a total station and excavation depth by applying the Global Positioning System (GPS) (Computer Integrated Construction Research Program, (2010): (Building Research Association New Zealand, 2014); Balakina, Simankina, & Lukinov., (2018); Computer Integrated Construction Research, (2019). Whereas, the site utilising planning consists of documents which depict the location of temporary facilities within the construction site boundary (Deshpande & Whitman, 2014). This is in line with Gledson & Greenwood (2016) which established that 4D modelling involves much more than mapping a model to a sequence. Moreover, they further added that it involves the integration of project controls, costing, resourcing, design and fabrication, warehousing procurement, site logistics and other functions with outputs in many different formats. Furthermore, Balakina, Simankina, & Lukinov., (2018) revealed that the application of 4D enables the detection of design errors earlier, allowing the optimization of the construction such as: optimizing the operation of cranes, the placement of building structures and materials at different stages of construction, optimizing the organization of work and to monitor the activities related to the preparation of the construction site for the compliance of labour protection and safety engineering.

Surprisingly, the construction system design (virtual mock-up) is ranked in third place for the uses of BIM in the construction phase. This is because the respondents are mostly from G7 contractors and producing this mock-up system is normally done by sub-contractors. However, as presented in BIM-based projects, the respondents agreed that creating and constructing complex building systems such as formwork system, glass veneers, anchor systems (Computer Integrated Construction Research Program, (2010); (Chou & Chen, 2017); Group Computer Integrated Construction Research, (2019) and building façades (Maing & Vargas, 2013) into a mock system are crucial. This virtual mock-up is essential as to visualize the complex building information model in a virtual perspective rather than merely a 2D plan. It facilitates the project team to assemble and execute the installation process which displays the detail of materials, fabrication and specification (Leicht & Kumar, 2010); Maing (2012): (Ortiz, 2020).

The final significant use of BIM in the construction phase is a digital fabrication. As mentioned earlier, most of the respondents are from G7 contractors (main contractors) and digital fabrication is normally done by subcontractors or MEP contractors. Eastman et al., (2011) also explainedthat for contractors using BIM concerning off-site fabrication despite clash detection, construction analysis, planning, quantity take-off and cost estimating are normally used. It is also supported by Kent (2014) which declared that prefabrication is the third-highest use among commercial MEP contractors where the BIM Model can be downloaded into equipment that is used to automate processes such as ducting. Likewise, it is also in line with the studies by Hergunsel (2011) which revealed that walls, rooms and houses can be virtually designed and constructed with the Building Information Model and can be prefabricated with roughed mechanical, electrical, plumbing (MEP) components. Thus, the final MEP connections can be made once the prefabricated components are assembled on site.

5.0 CONCLUSIONS

From the findings, it can be deduced that six (6) uses of BIM were from the construction phase such as 3D coordination, site utilising planning, construction system design, digital fabrication, 3D control and planning and the record model are significant from the BIM-based project contractors perspective. Nevertheless, among these uses, 3D coordination and the record model are highly significant as these uses contribute to great impact for BIM-based projects. As such, 3D coordination allows early detection of clashes in projects and thus reduces the potential of issuing requests of information, changes the order and rework of the project. Consequently, it enables BIM-based projects to reduce the cost and time and subsequently increase the project quality. While for the record model, information related to the building such as architectural, structural and MEP elements are recorded and documented in the form of an as-built model during the construction phase, thus enabling the contractors more ease in submissions to the clients. Moreover, it also allows the clients to properly manage and utilize the usage during the maintenance and operation phase during the later stage.

This paper has been presented as part of an ongoing PhD programme to develop a BIM adoption model for BIM-based project contractors. As per the methodological level, *SPSS* version 23 has been used in the development of the quantitative approach. Hence, this study also provides vital practical implications on the development of BIM uses especially for BIM-based project contractors. It would benefit and provide insights to other BIM-based project contractors in adopting BIM uses for their projects.

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