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Investigating Significant Issues of BIM Implementation in Industrialised Building System Design and Production Process

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Abstract: Industrialised Building System (IBS) has been considered a construction method to accelerate the development of the construction industry in attempt to boost the economic growth of Malaysia. With the slow uptake of IBS method in Malaysian construction industry, Building Information Modelling (BIM) technology was introduced as an IBS catalyst to improve IBS process in term of its productivity and efficacy. However, the advantages of BIM implementation are not fully acquired in IBS industry. Therefore, there is a need to investigate the issues encountered when BIM is implemented in IBS design and production process in Malaysia. The preliminary study adopted the concurrent triangulation mixed method approach where both semi-structured interview and qualitative survey are used as research technique. Four semi-structured interviews were conducted as qualitative survey with the industry experts who have more than 5 years of experience in both IBS and BIM fields to gain insight into the issues of BIM implementation in both IBS design and production process. The quantitative survey Likert scale of agreed level was indicated by the respondents simultaneously while investigating the issues of BIM implementation in IBS design and production process during the interview. The interview data was collected and analysed by measuring mean agreed level to issues of BIM implementation in IBS design and production process and identifying the most significant issues of BIM implementation in IBS process across responses from interview using excel tool and content analysis. The results showed that the most significant issues are encountered when BIM is implemented in IBS design process rather than in IBS production process. The most significant issue is the lack of early collaboration among IBS players in the beginning of IBS design stage in a BIM project. In addition, the lack of knowledge and understanding on IBS design and installation among the project stakeholder, especially consultants in the BIM integrated projects leads to the increase of IBS design time and causes the late confirmation of informed decision of the IBS component design. It can further affect the productivity of IBS production process. Therefore, the issues of BIM implementation in IBS design process should be tackled early to improve the BIM implementation in IBS industry in Malaysia.

Keywords: Building Information Modelling, BIM implementation, prefabrication, design process, production process, construction industry

1. Introduction

Building Information Modelling (BIM) is defined as a modelling technology and associated set of processes to produce, communicate, analyse and use of digital information models throughout the construction project life-cycle (CIDB Malaysia & Ministry of Work Malaysia, 2016). BIM is considered as an IBS solution to enhance the productivity and efficiency of the IBS process by improving the IBS design coordination (Currer & Pickup, 2012). It enables the collaborative and automated processes to improve the quality of IBS design (Kaner et al., 2008; Samarasinghe et al., 2016). BIM also gives the benefits to reduce material costs, site disturbance and air pollution, and improve the flexibility

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of design change and reuse of IBS components (Zhang et al., 2018). It reduces the lead time of design to fabrication through the automation manufacturing process of IBS components (Kaner et al., 2008). BIM also enable the automatic generation of schedule and cost budget process for eliminating project delay and improving cost accuracy (Currer & Pickup, 2012; Golaszewska & Salamak, 2017).

Despite many BIM solutions for IBS issues, there is still no fully acquired BIM advantages in IBS industry due to the inconsistent, unreliable, and untimely information exchange and lack of visibility and traceability in real time (Li et al., 2018). Therefore, this raises the importance to study the issues of BIM implementation in IBS design and IBS production process in order to utilise the BIM benefits when BIM is implemented in IBS construction.

2. IBS Development in Malaysia

Construction Industry Development Board (CIDB) introduced the definition of IBS as a construction technique whereby building components are manufactured in a controlled environment (on or off-site), transported, positioned and assembled into a structure with minimal additional site works (MIDF Research, 2014). IBS has been implemented in Malaysia since 1966. There are many initiatives that have been launched under the Construction Industry Transformation Programme (CITP) to address the IBS technology implementation in Malaysia toward a modern, highly productive and sustainable industry.

The traditional and routine way of doing construction is renounced gradually in the era of acceleration of technological progress. Accordingly, the power of mechanisation, automation and smart technologies are tackled in enhancing construction productivity (Lim, 2018). IBS is an alternative building construction method to enhance efficiency and productivity within the construction industry. It can improve the quality of construction with cost-effectiveness and shorter construction time. Dato` Ir Ahmad` Asri Bin Abdul Hamid, CEO of CIDB Malaysia claims that IBS not only can quicken the completion time but also reduce the cost of building materials and manpower during the labour shortage period. IBS is estimated to reduce 50% of construction time while helping the construction industry to cut down the number of workers by up to 50% which results in reducing 14% in labour costs in their projects (Karib et al., 2016). Karim (2018) had reported that Gamuda IBS shortens the construction period by one-third by using one-third of manpower compared with the conventional method. It also reduces dependency on foreign labour by 63% while producing a more skilled workforce. Apart from that, prefabrication in a controlled factory environment also brings the advantages of reducing construction wastage and material cost while allowing for close monitoring of energy usage toward sustainable construction. It reduces downtime due to adverse weather conditions as fewer construction activities take place on-site. It promotes site safety by providing a cleaner and tidier workplace environment. These benefits are resulting from the building components to an exact requirement which is closely monitored and standardised in a controlled environment of a factory (MIDF Research, 2014; Zhong et al., 2015).

However, the adoption of IBS in Malaysia has already lagged 20 years behind compared to other developed countries (Bersama, 2018), and the level of IBS implementation is still low (Shukor et al., 2016) which doesn't meet the government targets in Malaysia (Nawi et al., 2018).

2.1 Drawbacks of IBS Design and Production Process

Despite the many theoretical and practical advantages of IBS, there are several issues revolving around IBS design and production processes. Nawi et al. (2018) claimed that the issues of the disintegration and communication process in the IBS project in Malaysia are mostly during the design stage. The study found that the lack of integration among the relevant stakeholders and poor practice of design interaction is caused by inefficient design coordination between architectural, structural and mechanical and electrical detailing. It causes the occurrence of design collision (Li et al., 2011) and the need to redesign work that incurred the additional cost and delay in the completion of the M&E works.

Besides, Zhang et al. (2018) concluded that long lead times are required for optimising the IBS designs at the earliest stages of the project by performing design review and analysis of structural, sustainability and building performance of the IBS components. Apart from that, it is difficult to design integrated building service system, such as HVAC and electrical service for IBS building due to space restriction and clash with other design disciplines (Samarasinghe et al., 2016). The space restriction for integrated building service system is caused by the lack of collaboration between architect and M&E engineer during the early design stage. Building service system always comes after the architectural and structural design. Therefore, the collaboration and coordination of data and information among the design disciplines crucial for identifying where clashes and interference occurred among the IBS construction during the planning and design phase in order to improve the productivity of engineering design and production.

Moreover, the lack of IBS knowledge among the project stakeholders leads to the high risk of miscalculation and omission and reduce the accuracy of IBS project cost. In addition, a lack of knowledge on the IBS installation technique leads to a high risk of danger in IBS construction and reducing IBS safety and efficiency benefits (Samarasinghe et al., 2016). The cost misconception that the IBS method is more expensive than the conventional construction method and appearance misconception which is the complex and inflexible design of IBS with the integrated building service system will lead the project stakeholders to lack of confidence to adopt the IBS method in the construction industry. The restraint of the conventional mindset among the project stakeholders is the barrier to IBS implementation (Fauzi et al., 2018; Jaillon & Poon, 2010).

Poor communication between the structural engineering and prefabricated manufacturer lead to inadequate planning and scheduling of prefabrication production. It not only causes project delay and cost overrun but also affect the quality of information that results in the production of defective prefabricated building components (Fauzi et al., 2018; Samarasinghe et al., 2016). The characteristics of inflexible change in IBS design which is unable to modify the IBS components after the IBS building component is produced. The design collision may occur due to inadequate communication during the design stage, hence, causes redesign work that incurred the additional cost and delay in the completion of the M&E works. Inadequate communication can affect the benefit of waste reduction and the productivity of the IBS production process.

However, BIM technology had been recognised as a solution for enhancing the IBS process (Wu, 2017). BIM as an information flow management platform is capable to enhance collaboration among stakeholders by improving project information flow throughout the project life-cycle (Eastman et al., 2011). Mostafa (2018) asserted that BIM-IBS integration minimizes the final model deviation between designers and manufacturers due to seamless information exchange and effective collaboration via BIM system. In addition, BIM integration also shortened the procurement schedule by early identification of long completion time in the IBS process. Therefore, BIM should be introduced to increase the productivity of the IBS process.

2.2 BIM as A Core Processor for IBS Construction

The BIM technology should be adopted in the IBS design and production processes in order to improve the productivity and efficacy of IBS construction. BIM is introduced to address the fragmentation, poor project coordination and information management issues in the construction industry (Eastman et al., 2011). BIM provides a digitized built environment for all project stakeholders to store, manage and share information (World Economic Forum, 2018). BIM was introduced in the construction industry in Malaysia in 2007 by the Public Works Department (JKR) in order to improve the productivity and efficiency in delivering and managing the construction project of Government Malaysia. However, BIM implementation lags behind the countries like US, China and Australia while the low adoption of BIM in the construction industry due to the lack of professional that trained in BIM and the high initial cost of software and implementation (Carvalho, 2015; Yaakob et al., 2016).

BIM is modelling technology and associated set of processes to produce, communicate, analyse and use of digital information models throughout construction project life-cycle (CIDB Malaysia & Ministry of Work Malaysia, 2016). Besides, Sacks (2008) had mentioned that BIM acts as a tool for the structural analysis, design and detailing while enables data to be organised and used/reused during facility management in helping the document transactions, identify data requirements specific to disciplines and make a business decision to improve cost-performance value. BIM also provides the collaboration platform/work process for project stakeholders during the project life cycle. BIM can eliminate inefficiencies, enhances productivity, and enhance collaboration and communication among stakeholders in order to reduced project costs and time, and improved project productivity and quality (Yusuf et al., 2015). Furthermore, BIM has technical benefits in delivering comprehensive information among the key stakeholders in the supply chain by 3D visualisation, automatic generation of construction drawings, and schedule and cost estimation from BIM models.

BIM has been considered as an alternative to address the issues encountered in IBS design and production in Malaysia. BIM provides the platform to integrate key stakeholders from different design disciplines to facilitate collaboration during the design process (Yaakob et al., 2016). BIM overcomes the inadequate communication that lead to inaccurate data via collaboration and automates the design process. BIM acts as a rich information model to provide and manage the entire information of building throughout the project life cycle. Biswaroop Todi et al. (2018) claimed that the rich digital model becomes the product in industrialised production. For example, it provides precise digital spatial information of IBS building component such as dimensions and location for IBS design analysis (Wu, 2017). BIM also enables the 3D simulation and visualization to support the integration of structural engineering and building service systems such as HVAC and electrical service in IBS design (Yaakob et al., 2016). Moreover, it can perform structural analysis, sustainability and building performance analysis in order to produce optimized IBS integrated design and improve the efficiency of the IBS design review (Samarasinghe et al., 2016). BIM simulation and visualization also improve the inefficient design coordination among key stakeholders for clash detection. Clash detection helps to identify where clashes and interference have existed among architecture, structure and MEP systems during the planning and design phase (Currer & Pickup, 2012). The key stakeholders can prompt a response to correct the design error in 3D virtualisation (Patwari et al., 2018).

Besides, BIM eliminates the design errors from the occurrence after the IBS component being produced and the need for the reproduction of IBS building components that lead to an incursion of cost and time addition (Li et al., 2011; Mostafa et al., 2018). In addition, the automatic generation of IBS shop drawing from the BIM model can reduce the drafting time and lead time of engineering production (Kaner et al., 2008; Samarasinghe et al., 2016). It also reduces the inconsistency and discrepancy in IBS design (Mostafa et al., 2018). With rich information in the BIM model, it gives the advantages of improving the flexibility of IBS design change and reuse of the IBS component (Zhang et al., 2018). BIM enables the automatic generation of a cost budget and accelerates the production of material take-offs for the cost estimation and reduce the risk of miscalculation and omission caused by oversights in human factors that improve its accuracy. BIM also provides greater prefabrication project insights regarding the cost, schedule and constructability during the early design and planning phase (Golaszewska & Salamak, 2017; Yusuf et al., 2015). It raise the confidence of project stakeholder to increase the potential use of prefabricated construction method (McGraw-Hill Construction, 2011).

2.3 Setbacks of BIM Implementation in IBS

However, the advantages of BIM implementation cannot be fully acquired in the IBS design and production process due to the inconsistent, unreliable, and untimely information exchange and lack of visibility and traceability in real-time. Insufficient well-formatted, timely and right location of the prefabricated building component information cannot enhance the efficacy of project collaboration and decision making in IBS projects (Li et al., 2018). Besides, BIM implementation requires experts who have in-depth knowledge of building practices and procedures, as well as extensive resources (Lu & Korman, 2010).

The coordination issues between Architect, Structural Engineer and M&E engineer which occurs during the design review resulted in taking long lead times for optimising the designs at earlier stages of the project due to late decision making. Currer & Pickup (2012) reported that the project stakeholders are difficult to make an informed decision and plan for the BIM implementation in the prefabricated construction industry due to the lack of appropriate BIM knowledge among the stakeholders. Thus, the lack of relevant knowledge among the people can result in late decision making.

Interoperability problems happened when there are different software or software version used among the project stakeholders in the project design process. It can be comprehended in another way that the function of the Industry Foundation Class (IFC) translator exports the IFC model type that is not completely supported by another importing application translator. There is the loss of data and information during the model exchanging process that cause the need for rework in design modelling and resulting in the possibility of errors in design (Currer & Pickup, 2012).

A conceptual framework is built on the development of IBS and how BIM is realized as illustrated in Fig 1. First, it demonstrates on about the development of IBS industry and the drawbacks which affect the IBS development. Then it is followed by identifying how BIM acts as a solution to the issues of IBS development. This paper also investigates the setbacks of BIM implementation in IBS industry as it affects and minimizes the BIM advantage to IBS industry. It also directly relates and affects the IBS development in Malaysia. Thus, it is crucial to identify the significant issue of BIM implementation in IBS industry for further research to develop a model for the effective BIM implementation in IBS construction in this preliminary study. However, there is only a limited amount of literature specifically investigating issues of BIM implementation in IBS industry with respect to IBS design and production process. Therefore, the interview survey was conducted with four experts in IBS and BIM to investigate the significant issues of BIM implementation encountered in IBS design and production process in Malaysia.

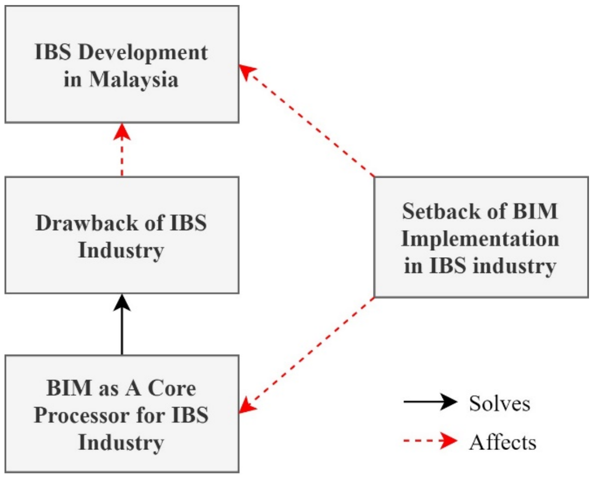

Fig. 1 - Conceptual framework

3. Research Methodology

The research was carried out using a mixed-method approach with the concurrent triangulation design. A combination of qualitative and quantitative data collection methods was conducted concurrently at this research (Almeida, 2018). It aims to capture more accurate and in-depth information from the industry experts as the respondent by cross-validating the main findings through further explanation from one single research method (Kroll & Neri, 2009; Sánchez-Hernández, 2018). It is similar as the method triangulation which was introduced in book of UNAIDS Monitoring and Evaluation Fundamentals (Rugg, 2010). It also found that there is a similar research which adopted the concurrent triangulation mixed-method design to cross-validate and provide explanation in-depth for the findings of both quantitative and qualitative data collection method (Sánchez-Hernández, 2018). It facilitated the researcher for more comprehensive and in-depth understanding of the pragmatic production process in the investigation of the impact of sociocultural adaption. Therefore, this preliminary study conducted a semi-structured interview with the BIM-IBS industry experts and collected quantitative data using the Likert scale to investigate the issue of BIM implementation encountered in IBS design and production process. A research methodology flowchart is illustrated in Fig 2.

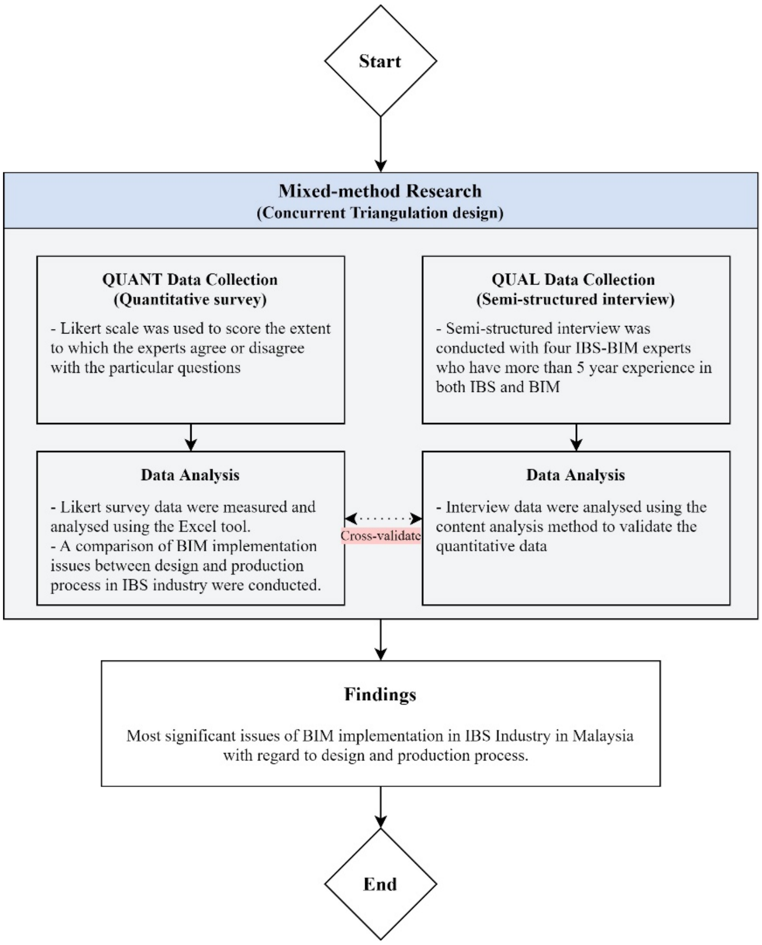

Fig. 2 - Research methodology flowchart

The semi-structured interview was selected as the data collection technique in this research due to its characteristics of open-ended responses from respondents for more in-depth information. It also guides the respondents to learn answers to questions and contribute more explanation on their opinions and answers (Fuel Cycle, 2019; Mack et al., 2005). Meanwhile, it allows the interviewer to explore responses and theme for further study (Oates, 2005). Meanwhile, the quantitative survey was adopted concurrently by using Likert scale which used as a survey scale to determine the respondents' attitudes by asking the extent to which they agree or disagree with a particular question.

The selected respondents were restricted to the IBS design and manufacturing experts who have at least five years' experience in IBS using BIM in the central and southern region of Malaysia. Azman et al. (2011) claimed that IBS designer and manufacturer are key IBS player in successful IBS development. They contributed more in-depth information about the issues of BIM implementation in the IBS process from their perspectives and experience. The research also restricted to the IBS design and production process. A total of four IBS experts using BIM have participated in this preliminary interview survey. Their general information is shown in Table 1.

Table 1 - General information of interviewed experts

Expert	Stakeholders	Experience in IBS-BIM (years)
A	IBS Manufacturer	18
B	IBS Manufacturer	5
C	IBS Designer	10
D	IBS Designer	18

During the interview session, all four experts were asked questions about the issues of BIM implementation encountered during both the IBS design and production process. It is then followed by rating the agreement level for each potential BIM implementation issues encountered in both IBS process on a five-point Likert scale which are 1 (Strongly disagree), 2 (Disagree), 3 (Neutral), 4 (Agree) and 5 (Strongly Agree). They also commented in detail on each issue according to their experience and perspective as the open-ended response characteristics of the semi-structured interview.

The interview questions were developed under several broad headings in the following.

- Section A: General Information of Experts
- Section B: Issues of BIM Implementation Encountered in IBS Design Process
- Section C: Issues of BIM Implementation Encountered in IBS Production Process
- Section D: BIM Contribution in IBS Design and Production Process
- Section E: Recommendations to Overcome the IBS Design and Production Process Issues

In Section A, it consisted of some demographic questions to gain insight on the respondent's background such as name, job title, company, and work experience in IBS using BIM. Then it is followed by Section B and C, which comprise of the Likert scale questions regarding the potential issues of BIM implementation encountered in the IBS design and production process. There are nine BIM implementation issues encountered in IBS design and eight in IBS production as shown in Table 2 and 3. The interview aimed to investigate the significant issues of BIM implementation in the IBS design process. All potential issues are extracted from the existing study through a literature review. An in-depth discussion on the issues in the IBS design and production process was taken to figure out the most critical issues and other issues among the issues listed. Besides, the experts were asked to contribute their perspective and opinion on how the implementation of BIM technology improves IBS design and production process and the recommendations to overcome these issues as listed in Section D and E.

In concurrent triangulation mixed-method design, the qualitative and quantitative data were collected and analysed at the same time to enhance the depth and scope of findings (Kroll & Neri, 2009). For the quantitative data, the Likert survey data was analysed the industry experts' attributes using an excel tool that represents the extent to which they agree or disagree on the issues of BIM implementation encountered in IBS design and production process during the semi-structured interview. Meantime, the interview data were analysed using the content analysis to synthesise and validate the quantitative data in order to identify the significant issues of BIM implementation encountered in IBS design and production process. Then it is followed by the comparison of BIM implementation issues between the IBS design and production process. Besides, the way forward to overcome the issues of BIM implementation in IBS design and production process was captured across responses from the different perspectives of the experts.

4. Results and Discussion

This chapter covers the results and discussion of the issues encountered of BIM implementation in IBS design and production process, comparison on BIM implementation issues in IBS design and production process, and way forward to overcome the issues of BIM implementation in IBS design and production process. The interview data were tabulated and analysed across responses from the interview.

4.1 Issues of BIM Implementation in IBS Design Process

The mean value of the Likert survey for the issues of BIM implementation in IBS design process is calculated as shown in Table 2. The highest mean for the issues encountered when BIM is implemented in IBS design process is 3.75 for the lack of collaboration among the relevant players in the early stage of designing IBS components (D5) and long cycle time for design review leads to increased design time (D6). Based on the interview finding, the experts found that the appointment of IBS players is significant at the beginning of the project, instead of after the project commences. This is supported by a previous study that the involvement of contractor always came after the design phase which leads to a lack of their contribution for the opinion in IBS design and construction aspect (Jabar et al., 2013). Besides, the poor collaboration also brought up an issue of insufficient information among the stakeholders in the IBS design process (Ismail, 2018). The long cycle time for design time (D6) is due to the late decision making on the design proposal during the early planning and design stage and also the cross-checking and interaction between architectural and structural drawings that lead to low IBS design production rate (Zhang et al., 2018). Then, followed by unstructured information exchange and interaction of design data leads to inaccurate data (D8) which attained a mean agree level of 3.50 as the result of most of the respondents stand at a neutral response on it. The result aligned with the findings of Migilinskas (2013) that the majority of project stakeholders are used to engage with the different designing tools which often leads to uncompleted data transfer since there is a lack of structured information exchange and management (Migilinskas et al., 2013). The loss of data and information during the model exchanging process would cause the need for rework in design modelling and increase the possibility of design errors occurrence (Currer & Pickup, 2012). Most experts were strongly disagreed with the lack of standard or guideline in IBS design (D9) as an issue which resulted in the lowest mean agree level of 1.75. Expert A and D reported that there are the typical design codes and guidelines adequately covered but not being properly followed and enforced by project stakeholders.

Table 2 - Issues of BIM implementation encountered in IBS design process

	IBS Design Issues	**Mean Agree Level**
D1	Low IBS drawing production rate	3.25
D2	Design and drafting errors occur frequently in IBS drawing.	2.50
D3	Logistic constraints of IBS components lead to design limitations	2.50
D4	Lack of communication between different parties in terms of design information flow	3.00
D5	**Lack of collaboration among relevant players in the early stage of designing IBS components**	**3.75**
D6	**Long cycle time for design review leads to increased design time**	**3.75**
D7	IBS designs are not flexible	2.00
D8	Unstructured information exchange and integration of design data lead to inaccurate data	3.50
D9	Lack of standard or guideline in IBS design	1.75

From the experts' responses, the low IBS drawing production rate (D1) is not an issue when BIM is implemented during the IBS design process. Expert A explained that IBS drawing production rate depends on the complexity and quality of building design. With BIM technology, it can be addressed with design coordination among different disciplines on the same integrated BIM model platform and which also improve the quality of complex building design with BIM 3D design coordination feature for the cross-checking between different discipline drawings (Wang et al., 2014). BIM software also provided the automatic drawing production feature that improves the productivity of IBS drawing (Samarasinghe et al., 2015).

Besides, most experts disagreed that the logistic constraints of IBS components lead to design limitations (D3) and inflexible IBS design (D7). Expert A and C justified that the lack of knowledge and understanding of using IBS led to the wrong perception of IBS design (Jabar et al., 2018). Expert B also claimed that the modularization concept in IBS construction can diminish the logistic constraints and IBS design limitation by designing the mix and match components concerning space and building standards that can be delivered and assembled at the site (Jaganathan et al., 2013).

Apart from that, most experts were hesitant about the lack of communication between different parties in terms of design information flow issue (D4) in the IBS industry using BIM implementation. Expert C was revealed that the conventional mindset among stakeholder makes them reluctant to adopt both BIM and IBS skill and concept in the project. It is the reason for the lack of support and collaboration among stakeholders (CIDB Malaysia, 2018; Farooq et al., 2020). Expert D was highlighted that the ignorance of the importance of IBS and BIM in the industry can be an issue that leads to difficulties in collaborating and integrating BIM into IBS process. This point is also supported by the research of Migilinskas et al. (2013).

Expert A and C also found that the lack of experience on IBS and BIM hinders the successful BIM implementation in the IBS industry. The project stakeholders find it difficult to make an informed decision and plan to implement BIM in the prefabricated construction industry. It leads to the design and drafting errors that occurred in IBS drawing and late design changes on IBS components' size which can affect the overall planning of IBS mould fabrication and its production process.

4.2 Issues of BIM Implementation in IBS Production Process

Table 3 displays the issues of IBS implementation in IBS production process. The issue with the highest mean of agree level was unstructured information exchange and interaction of design data leads to inaccurate data (P6) with a mean of 3.25, followed by limited knowledge and skills about manufacturing-based approaches (P8) which is 2.75 and lack of innovation and technology application of the Automation and Robotic industry to support the prefabrication process (P7) which rated at 2.50. It was explained by Expect A that it is very demanding on the experienced personnel and automation and robotic technology in the IBS industry. It requires a big capital expenditure for the personnel training and investment of automation and robotic technology. Expect B also further discussed that the innovation and technology are available but not widely used due to demand and cost constraints (Yaakob et al., 2016).

Besides, the issues found to be of the least significance include IBS supply chain management is complicated (P3) and IBS production rates are low because of the lack of design repetitions (P5) which had obtained the same mean agreed level of 1.75. It was interpreted by Expect A that IBS supply chain management has been matured in Malaysia for years, IBS experience and understanding of the optimised design of moulds of IBS player has accelerated the IBS production rate. Conversely, Expect C reported that knowledge and skills in the manufacturing process are very limited. It was proven in other studies that IBS have been implemented in Malaysia since 2007, but IBS implementation still low and lagged than other developed countries (CIDB, 2017; Shukor et al., 2016). Expect B also clarified that the efficiency and productivity of IBS component production rely on early planning and resources allocated. The quality can be ensured due to IBS components are produced in a factory with a controlled environment that provided a defined process with quality control. It is aligned with the findings of other studies (MIDF Research, 2014; Zhong et al., 2015). Overall, the results indicated that most of the issues of BIM implementation in IBS production had a very low response mean which is lower than 2.50. It marked that there are fewer significant issues of BIM implementation in the IBS production process.

Table 3 - Issues of BIM implementation encountered in IBS production process

	IBS Production Issues	Mean Agreed Level
P1	IBS component production process is not efficient.	2.00
P2	IBS components produced are poor quality.	2.00
P3	IBS supply chain management is complicated.	1.75
P4	Lack of real-time information (monitoring, feedback and update from another party) leads to inefficiency in IBS production.	2.25
P5	IBS production rates are low because of the lack of design repetitions	1.75
P6	**Unstructured information exchange and integration of data lead to inaccurate data exchange.**	**3.25**
P7	Lack of innovation and technology application of the Automation and Robotic industry to support the prefabrication process.	2.50
P8	Knowledge and skills about manufacturing-based approaches are limited.	2.75

Expert B claimed that the efficiency of any production process depends on early planning and resources allocated regarding issue P1 as listed in Table 3. BIM enhance the collaboration among stakeholders by providing a collaborative platform to work simultaneously as a team on one BIM model (Singh et al., 2018). However, the lack of collaboration among relevant players in the early stage of designing IBS components in the IBS design process hinders the early planning and decision making for the IBS production work. Besides, Currer & Pickup (2012) claimed that the unwillingness of IBS industry to change mindset and attitude is the biggest obstacle to adopt BIM technology and invest in research and development (R&D) in his research. It leads to the lack of appropriate BIM knowledge and adoption strategy in the IBS industry which affects both IBS design and production process. It is in line with the experts' opinion on the issue of BIM implementation encountered during IBS design and production in this research.

Apart from the issues above, Expert C revealed other issues which are late confirmation of sizes & type of components and delay in payment. The late confirmation of IBS component design caused the delay of IBS production and further affected the whole supply chain of IBS construction. In addition, the payment to the IBS manufacturer is vital due to the incursion of the high initial cost of the IBS project to determine the production rate of the IBS component (Nawi et al., 2019). Expert D also commented that the main reason for IBS is not implemented among the construction industry in Malaysia is due to the high cost of IBS production leading to low demand in the Malaysia construction industry (Samarasinghe et al., 2016).

4.3 Issues of BIM Implementation in IBS Process: Design versus Production

Figure 3 illustrates the combination of IBS design and production issues when BIM is implemented. As is evident from the figure, it was apparent that the most significant issues of BIM implementation are encountered in the IBS design process rather than the IBS production process. It can be seen that the top 5 highest mean rating issues were mostly encountered during IBS design process. The most significant issues of BIM implementation in IBS process are lack of collaboration among the relevant players in the early stage of designing IBS components (D5) and long cycle time for design review leads to increased design time (D6). Both issues prevailed failure of BIM collaboration in IBS process and hinder the integration of construction knowledge among IBS players and stakeholders (Nasrun et al., 2010). In order to adopt BIM's benefits as a collaboration and communication platform, it's important to appoint IBS players in the beginning stage of the project. The earlier involvement of IBS players in IBS design stage for design coordination and review promotes accurate decision on IBS design and reduce the iterative between design and analysis cycle. Despite issues on collaborative working practice, adopt BIM-based collaborative design lead to issues of data loss as stakeholders use a different type of software application according to respective task (Oh et al., 2015). This statement is strengthened by the findings of this study which both IBS design and production process experienced issues on unstructured information exchange and interaction of design data leads to inaccurate data (D8, P6). The fifth issue in the rank is the low IBS drawing production rate (D1) encountered when BIM applied in the IBS industry.

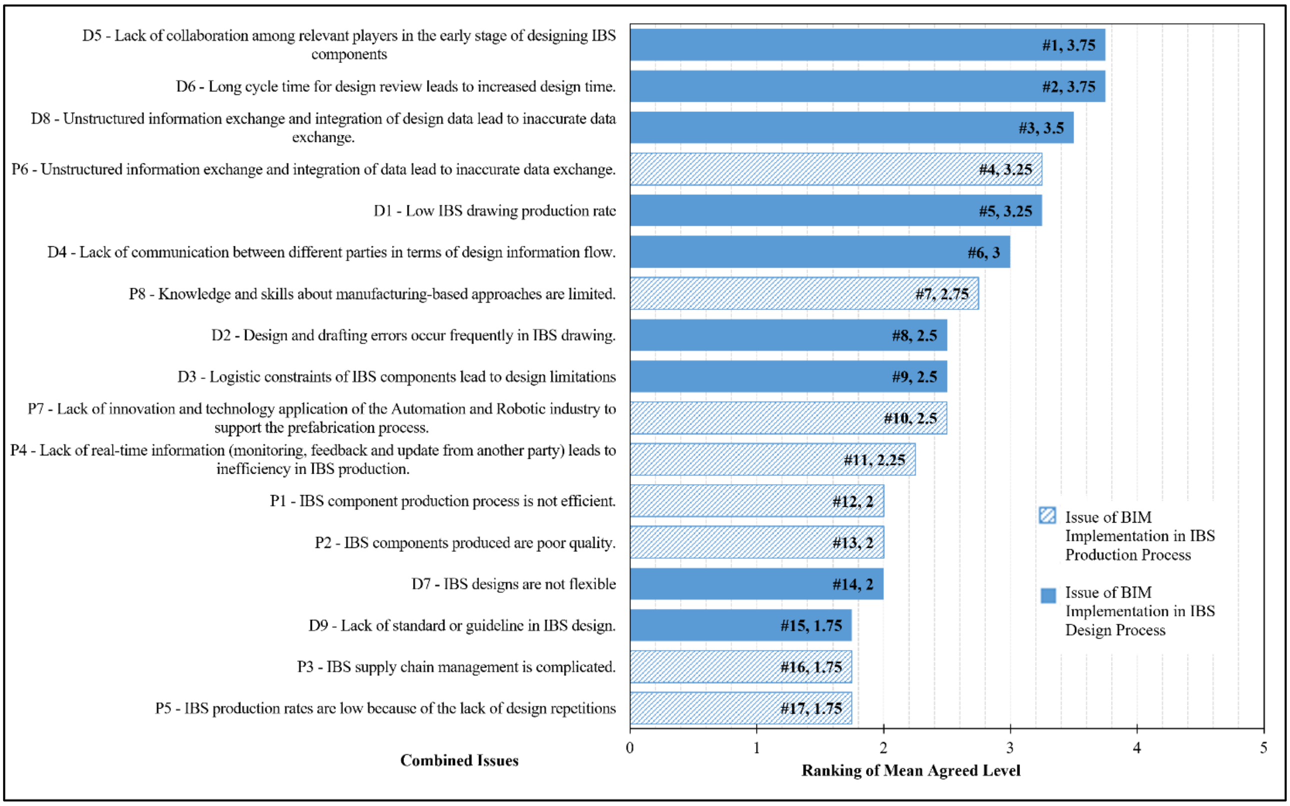

Fig. 3 - Mean agreed level for issues of BIM implementation in ibs design vs. production process

From the qualitative interview, it was found that the IBS drawing production rate is subjected to the design issued tackled in preliminary design as the design time is dragged by the cross-checking and interaction between architectural and structural drawings. Therefore, the coordination among the key players is important for delivering project information using the BIM process through the project life cycle to ensure the consistency and accuracy of design data among all stakeholders toward high quality and efficiency of IBS production in the industry. Besides, Currer & Pickup (2012) encouraged the IBS industry to invest in research and development about the adoption of ICT to enhance the BIM knowledge and adoption strategies in order to improve the IBS implementation coupled with BIM technology.

4.4 Way Forward to Overcome the IBS Design and Production Process Issues

There is some way forward to overcome IBS design and production issues from the interviews. From the designer perspective, Expect C revealed that 3D modelling needs to be employed to provide a view of IBS' finished product and also produce an accurate and precise material take-off for IBS production. The accurate and precise design information is further beneficial to IBS production in order to ensure the accuracy and efficacy of IBS production planning in manpower, material use and controlling wastage, thus leads to an increase in productivity. Expect D also emphasised the importance of general engineering design knowledge in the industry. It needs to be improved to enhance the quality, efficiency, and productivity of IBS component design in the IBS industry. Besides, Expect D also highlighted that the importance of the government in improving IBS implementation in Malaysia. The government needs more inventions to incentive the use of IBS in the industry. Therefore, it leads a result of addressing the issues when BIM implemented in the IBS design process.

From the manufacturer's perspective, Expect A strongly encouraged that the informed decision on drawing layout needs to be made with better communication among the stakeholders before the IBS shop drawing being produced. It can greatly reduce the occurrence of expensive changes and variations to the IBS design once the IBS production has commenced (Mahbub, 2016). Furthermore, it is pivotal to need for establishing quality operation procedures in the IBS production stage to produce quality IBS finished products in a controlled environment. Thus, it can greatly improve the issue of BIM implementation in the IBS production process.

5. Conclusion

The preliminary study found that the most significant issues of BIM implementation in the IBS design process rather than in the IBS production process in Malaysia. Based on the responses from the semi-structured interviews with respondents, the lack of collaboration among relevant players in the early stage of designing IBS components and long cycle time for design review leads to increased design time were identified as the most significant issues encountered when BIM implemented in IBS design process. It is indeed for the early involvement of all IBS players at the beginning of the project to enhance the early collaboration in designing IBS components in order to tackle early the design problem. The lack of knowledge and understanding of IBS design and installation among the project stakeholder, especially consultants in the BIM integrated projects leads to the increase of IBS design time and causes the late confirmation of the informed decision of the IBS component design. This also followed by causing the low production rate of IBS drawing plan. The results identified that the least significant issues are encountered when BIM is implemented in IBS production process. This study concluded that the early collaboration among IBS players is very crucial, especially when BIM implemented in the IBS design stage of the project. The accuracy and precision of IBS design information flow through BIM implementation enables informed decision making before the IBS production started. It can be greatly eliminated the issues encountered in IBS production process. Therefore, the issues of BIM implementation in IBS design process should be overcome early to promote the efficiency of BIM implementation in IBS industry in Malaysia. However, the further studies are needed to investigate the barriers and drivers to BIM implementation in IBS industry in order to improve the construction sector in Malaysia.

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