

# APPLICATION OF BUILDING INFORMATION MODELLING (BIM) IN DESIGN AND BUILD (D&B) PROJECTS IN MALAYSIA

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## Abstract

Design and Build (D&B) is one of the most suitable types of project delivery method that are being used to implement BIM. However, there is a lack of documented evidence to show on how BIM is being implemented in D&B project. This paper aims to explore the current practices of BIM in D&B projects in the Malaysian construction industry. A literature review was done to explore on application of BIM in construction projects and D&B project concept. Furthermore, semi-structured interviews with construction players were conducted as a primary data for this paper. The interviews were conducted with construction players that are currently involved and have experiences in D&B BIM projects. The findings revealed that the BIM process in D&B projects is much similar with activities in conventional D&B project. The differences were by the used of BIM software, the process of developing project design into a 3D model and the involvement of BIM related designation in the project. In addition to that, the process of BIM in D&B has been highlighted in this paper.

**Keywords:** *Building Information Modelling (BIM), Design and Build (D&B), Current Practices, BIM Uses, Construction Players, Malaysia*

## INTRODUCTION

For the past ten years, projects over budget, projects delay, and poor quality of projects are among the common problems that have been faced by the construction industry (Nagalingam, Jayasena and Ranadewa, 2013). These problems happened due to several challenges. In particular, the use of 2-Dimensional (2D) information in producing design contributed to the problems (Saini and Mhaske, 2013); thus, contributed to the miscommunication, duplication of information, and inaccurate of information among construction players (Zakaria et al., 2013). Most importantly, the involvement of various construction players in the conventional practice projects may also contribute to problems (Bryde et al., 2013; Crotty, 2013; Zakaria et al., 2013). This is because client, architect, C&S, and MEP engineers are working independently in producing the project design without coordinating their work with others (Crotty, 2013).

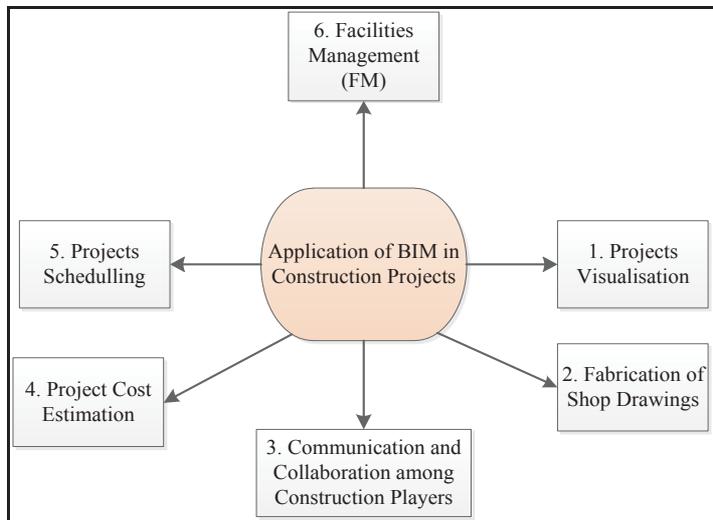
Hence, a massive gains need to be made in integrating all project teams with the structure of business lifecycle in construction industry that are being recognised by various project team (Marshall-Ponting and Aouad, 2005). In addition, the use of Information, Communication, and Technology (ICT) could also help to simulate a more standardised communication among construction players in construction projects (Ahuja, 2009). Otherwise, the current continuous problems in the industry could not be improved (Alaghbandrad et al., 2015). Based on that reason, Building Information Modelling (BIM) provides a solution to overcome the problems in effective and efficient ways by integrating BIM processes with the use of BIM software.

BIM is considered as a project and process simulation (Bryde et al., 2013; Kensek, 2014; Alaghbandrad et al., 2015) because it is a concept that could virtually show the planning and actual building of construction projects in 3-Dimensional (3D) modelling (Barnes and Davies, 2014; Kensek, 2014). Therefore, BIM could not be treated merely as a software tool. The use of BIM software must give impact on all processes within the construction projects (Azhar, 2011; Bryde et al., 2013). Thus, the benefits and resource saving during design, construction, maintenance, and operation of project has rendered a growing interest to adopt BIM in construction projects (Forbes and Ahmed, 2010; Arayici et al., 2012). BIM has been implemented in several types of project delivery method such as Design-Bid-Build (DBB), Design and Build (D&B), Construction Management (CM) (Eastman et al., 2011; Barnes and Davies, 2014), and Integrated Project Delivery (IPD) Method (Eastman et al., 2011; Porwal and Hewage, 2013; Kensek, 2014). Above all, D&B proved to be the most proficient and suitable type of project delivery method for BIM implementation (Eastman et al., 2011; Tsai, et al., 2014; Tsai, et al., 2014; Hardin and McCool, 2015), and it is easy in controlling and getting the full benefit of using BIM.

Despite its advantages, documented research that demonstrated on how well construction players implement BIM in D&B project and to what extend construction players use BIM in the D&B projects are still lacking. Therefore, this paper aims to investigate on the current practices of BIM in D&B project, specifically in the Malaysian construction projects. Literature review on the implementation of BIM and D&B concept are discussed in the next section.

**LITERATURE REVIEW ON IMPLEMENTATION OF BUILDING INFORMATION MODELLING (BIM) IN PROJECTS**

The use of BIM application has been expanded over construction project life cycle. It is used to achieve a better integration of project information, improvement of process in projects, and promoting collaboration from the pre-construction phase to post-construction phase (Barnes and Davies, 2014). Figure 1 shows the use of BIM application in construction projects.



**Figure 1.** BIM applications in Construction Projects

Based on Figure 1, there are several common BIM application in construction project which are projects visualisation, fabrication of shop drawings, communication and collaboration among construction players, project cost estimation, project scheduling, and Facilities Management (FM) (Azhar, 2011; Bryde et al., 2013). Details of each application are discussed as follows:

### **Projects Visualisation**

BIM helps construction players such as client, architect, civil and structural (C&S) engineer, mechanical, electrical and plumbing (MEP) engineer, quantity surveyor (QS), contractor and facilities manager to visualise a project before it project enters construction phase (Forbes and Ahmed, 2010; Azhar, 2011). By using BIM software, construction players specifically architect, C&S and MEP engineer are able to design and represent buildings with its component in a coordinated scale 3D model (Arayici et al., 2012). They commonly use BIM software such as Revit Architecture, Revit Structural, and Revit MEP to produce project design (Eastman et al., 2011; Hardin and McCool, 2015).

### **Fabrication of Shop Drawings**

BIM can also be used to generate shop drawings faster compared to traditional practice, which is in 2-Dimensional (2D). In the traditional practices, any changes in a design must reflect the assembly drawings. By using BIM, any changes will be entered into the 3D model and the erection is updated followed by the automatic generation of shop drawings. This makes the shop drawings produced to be more accurate with less time and effort as the construction players especially architect, C&S, and MEP engineer do not have to update the information manually (Eastman et al., 2011).

### **Communication and Collaboration among Construction Players**

BIM also increased communication and collaboration among construction players during the process of construction (Latiffi et al., 2013; Eadie et al., 2015). On top of that, BIM allows facilitating simultaneous work by multiple design disciplines (Eastman et al., 2011). By having communication and collaboration among construction players, high level of information transparency among them could be achieved by using BIM. As a result, the construction players could communicate and review the project information, gives feedback, and make decision regarding the project in less time than conventional construction.

### **Project Cost Estimation**

In addition, BIM provides capabilities to extract the counts of components, area and volume or spaces in building, materials quantities and later to be used to determine construction project's cost as well as for construction planning and management (Eastman et al., 2011; Barnes and Davies, 2014). A QS uses BIM software such as Exactel Cost-X and Vico Take Off to generate an accurate quantity take off and estimation (Monteiro and Martins, 2013). These tools provide varying levels of support for automated extraction and manual take off features (Eastman et al., 2011). By using BIM software, QS is no longer carry out manual estimation. Therefore, the quantities and cost estimation produced in a project using BIM is more accurate and reliable.

### Projects Scheduling

BIM could also be used to manage the schedule and planning of the construction projects (Hardin and McCool, 2015). A project manager and contractor for instance, uses BIM software such as Autodesk Naviswork to provide 4-Dimensional (4D) scheduling, to update and track the progress of work, to create a multidiscipline model, to simulate and optimise scheduling, and to identify and coordinate clashes projects (Eastman et al., 2011; Latiffi et al., 2013).

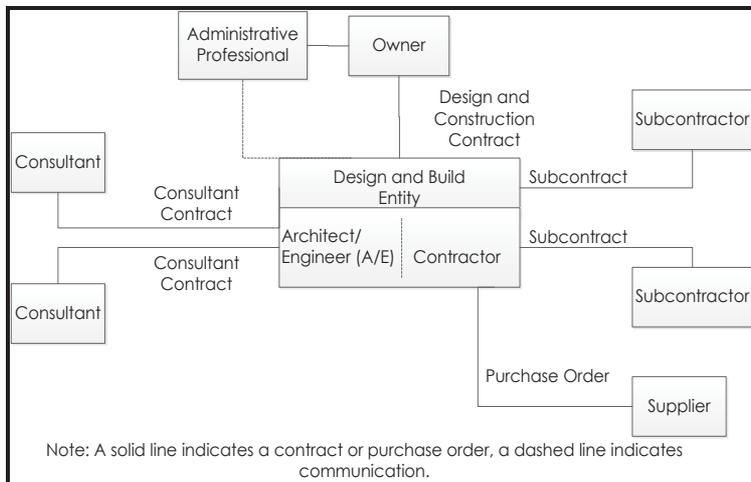
### Facilities Management (FM)

BIM is not limited to design and construction activities. It could also be used to maintaining the operation of building. Maintaining the information regarding the FM is much similar to maintaining the real facility. Facilities Manager uses BIM to upkeep, support, and maintains the completed building. Any components that replace, repair, remove or change will need to be up-dated (Bonanomi, 2016). Hence, the benefit of BIM for facilities management enable it to have an accuracy and up-dated building information model such as furniture, fixture, and equipment as well as the building occupants move in (Kensek, 2014).

### Design and Build (D&B) Concept

Design and Build (D&B) is the most common type of project delivery methods that are being used in projects using BIM (Linderoth, 2010; Eastman et al., 2011). It is used to overcome the failures of traditional construction delivery methods of construction project (DBB) (Gould and Joyce, 2009; Forbes and Ahmed, 2010). It is a concept where the contractor and the design consultant (architect, C&S, and MEP engineer) are in the same team in producing the design as well as contract documents based on the client’s requirement (Porwal and Hewage, 2013). D&B entity or team takes the responsibility for the major design and construction activities, together with the risk associated in a fixed fee (Barnes and Davies, 2014).

Figure 2 shows D&B contractual relationship and work process in conventional construction projects.



**Figure 2.** Design and Build (D&B) Concept (Construction Specifications Institute, 2011)

Based on Figure 2, a project client or owner is responsible to prepare project description. The description of project will be developed by an administrative professional in a separate entity. Meanwhile, the selected D&B team has an obligation to perform and deliver completed project based on the client specification. Commonly, the main contractor in the D&B team has its own design team which is architects and engineers (A/E) to offer D&B service to the client (Dobelis, 2013).

The A/E is responsible to develop project design including reviewing the client’s project description, preparation of preliminary design, detail design, and preparation of construction documents. Once the design is completed with an estimated cost, D&B team will hire a sub-contractor and suppliers to construct the project (Construction Specifications Institute, 2011). In return, the D&B team will return a completed project to the client.

Hence, a collaborative work that occurs in D&B project delivery method is more suitable to facilitate BIM (Eastman et al., 2011; Eadie et al., 2013). This is because D&B method allows to have an early involvement of construction players and allow for modifications to be made early in the design process. For that reason, the project could save time and money.

## METHODOLOGY

Data gained to achieve the aim of this paper was by means of literature review and semi-structured interview. A literature review was done to get explicit information regarding BIM uses, D&B concept, and the process involved.

Due to the limitation of construction players that involved in projects using BIM, a total of twenty-six (26) respondents have been identified to provide information related to BIM. A semi-structured interview with the twenty six (26) respondents that involved in BIM project have been conducted to get an in depth understanding on BIM process. As a result, eleven (11) of the respondents were found to involve in D&B projects. Various designation of respondents have been identified which are client, architect, C&S engineer, contractor, and BIM consultant.

The interviews were conducted to gain in-depth information on the involvement of various construction players in D&B projects using BIM, their experiences, BIM uses, and the process involved. The processes were by means of activities and sequences of work in implementing BIM. Those respondents were selected based on their willingness to share their experience.

A set of an interview questions was developed to obtain information on the process of D&B BIM project in the Malaysian construction industry. The interview questions consist of two (2) sections as shown in Table 1:

**Table 1. Interview Questions**

No	Section	Purpose
1	Section 1: Respondents' Background	<ul style="list-style-type: none"> <li>• To identify respondents' designation in D&amp;B project.</li> <li>• To get explicit information about respondents regarding years of experience in D&amp;B projects using BIM.</li> </ul>
2	Section 2: Current Practices of BIM	<ul style="list-style-type: none"> <li>• To identify the purposes of using BIM in D&amp;B projects.</li> <li>• To gain information on how BIM is being implemented by using D&amp;B concept.</li> </ul>

The interviews were recorded with permission from the respondents. Data gained were analysed by using content analysis technique. Content analysis is relevant to be used for analysing unstructured data such transcription of semi-structured interview. All data gained from the respondents were then analysed using Atlas t.i.7. Atlas t.i. enables to analyse visual and hierarchical modelling of concepts and theory. It merged with large amount of documents and keeps the data in all fields that require close study and analysis of primary material consisting audio, images, codes, video, and geo data (Ahmad Latiffi et al., 2016). All data were represented in the form of tables and figures.

The next session discusses on the findings and discussion on the respondents' experience, BIM uses and D&B process in the Malaysian construction projects.

## FINDINGS AND DISCUSSION

The implementation of BIM as a new concept in construction projects could change the current activities and process of construction players in a project (Bryde et al., 2013; Hardin and McCool, 2015). This section focused on the findings from the interviews with construction players in D&B BIM project. This section consists of 4 sections as follows:

### Respondents' Background

Respondents' background is important to ensure the selected respondents were appropriate to give information regarding BIM implementation in construction projects. From the data collected, all respondents' designation involves in D&B BIM projects were identified and presented in Table 2.

**Table 2.** Respondents' Designation in D&B Project using BIM

Respondent	Designation				
	Client	Architect	Civil and Structure Engineer	Contractor	BIM Consultant
R1					•
R2				•	
R3					•
R4				•	
R5				•	
R6		•			
R7		•			
R8					•
R9	•				
R10			•		
R11					•
<b>Total</b>	1	2	1	3	4

Based on Table 2, one (1) respondent (R9) held designation as a client. Two (2) respondents (R6 and R7) are an architect. Meanwhile, one (1) respondent (R10) is C&S engineer. Conversely, three respondents (R2, R4 and R5) involved as a contractor and four (4) respondents (R1, R3, R8 and R11) involved as a BIM consultant in project using BIM. Four (4) respondents (R1, R3, R8 and R11) involved as a BIM consultant.

### Respondents Experience in Implementing Design and Build (D&B) BIM Project

The purpose of this section is to explore on the duration and inception of BIM implementation among respondents in D&B projects. Table 3 shows the respondents' experience in D&B project using BIM.

**Table 3.** Respondents' Experience in D&B Project using BIM

Respondent	Designation									
	2015	2014	2013	2012	2011	2010	2009	2008	2007	2006
R11										
R10										
R9										
R8										
R7										
R6										
R5										
R4										
R3										
R2										
R1										
<b>Total</b>	1	2	1	3	4					

Based on Table 3, one (1) respondent (R7) has nine (9) years of experienced in D&B projects using BIM since 2007. Meanwhile, R11 has six (6) years of experience involving in D&B project using BIM. In the meantime, five (5) respondents (R1, R2, R3, R5, and R10) have five (5) years of experience in D&B BIM project since 2011. Temporarily, three (3) respondents (R4, R8, and R9) started to involve in project using BIM since 2012. Only one (1) respondent (R10) has three (3) years of experience to involve in BIM since 2013.

From the results, it can be concluded that the BIM has started to be used since 2007. This is in line with research conducted by (Ahmad Latiffi et al., 2016) who reported the use of BIM started in 2007. Hence, in order to explore on the current process of using BIM in D&B project, it is important to identify the purposes of using BIM in D&B project, which are discussed in the next section.

### Purposes of using Building Information Modelling (BIM) in Design and Build (D&B) Project

The purpose of this section is to explore how far the BIM is used in D&B project. Table 4 shows the purpose of using BIM in the construction project.

**Table 4.** BIM Uses in D&B Projects

Respondent	BIM Uses		
	Project Visualisation	Improve Project Design	Detect Design Clashes
R1	•	•	•
R2	•		•
R3	•		•
R4	•		•
R5	•		•
R6	•	•	•
R7	•	•	•
R8	•	•	•
R9	•	•	•
R10	•	•	•
R11	•		•
<b>Total</b>	11	6	11

Based on Table 4, there were three (3) purposes of using BIM in D&B project. The purposes were project visualisation, design review, and detect design clashes. From the table, all respondents have experienced using BIM for projects visualisation. BIM is used to help project client specifically to visualise a complete projects before the construction take place. Not limited to project client, BIM also helps other construction players such as architect and C&S to visualise and evaluate on the design produced effectively so that they could identify any discrepancies of design (Azhar, 2011; Eastman et al., 2011; Bryde et al., 2013).

Meanwhile, six (6) respondents (R1, R6, R7, R8, R9, and R10) experience using BIM to improve projects design. The respondents explained that the development of project design could be improved by using BIM software such as Revit Architecture and Revit Structural. Furthermore, the development of design into 3D model with project information could help to identify any discrepancies and conduct design analysis at an early phase. Added to that, BIM helps construction players to have a better design with less error by linking the design into 3D geometry with real time database (Eastman et al., 2011; Bryde et al., 2013; Dobelis, 2013; Ahmad Latiffi et al., 2014; Garber, 2014).

Moreover, all respondents were using BIM to detect design clashes. The respondents highlighted that most of the D&B BIM projects they involved were using BIM due to the capability of the concept in detecting design clashes. Clash detection is also known as a process in which used during coordination process to determine field conflicts by comparing 3D model of building systems (Eastman et al., 2011).

Therefore, from the BIM uses, the BIM process in D&B project could be identified. This is because the process of work is depending on the purpose of using BIM in project.

Next session discusses on the BIM process in D&B project.

### **Building Information Modelling (BIM) Process in Design and Build (D&B) Project**

This section discussed on the current process of BIM in D&B projects. The purpose of this section is to provide information on how construction players use BIM in construction

projects. The process is demonstrated based on the involvement of the respondents and BIM uses in D&B projects. Hence, the BIM process in D&B project is illustrated in Figure 3.

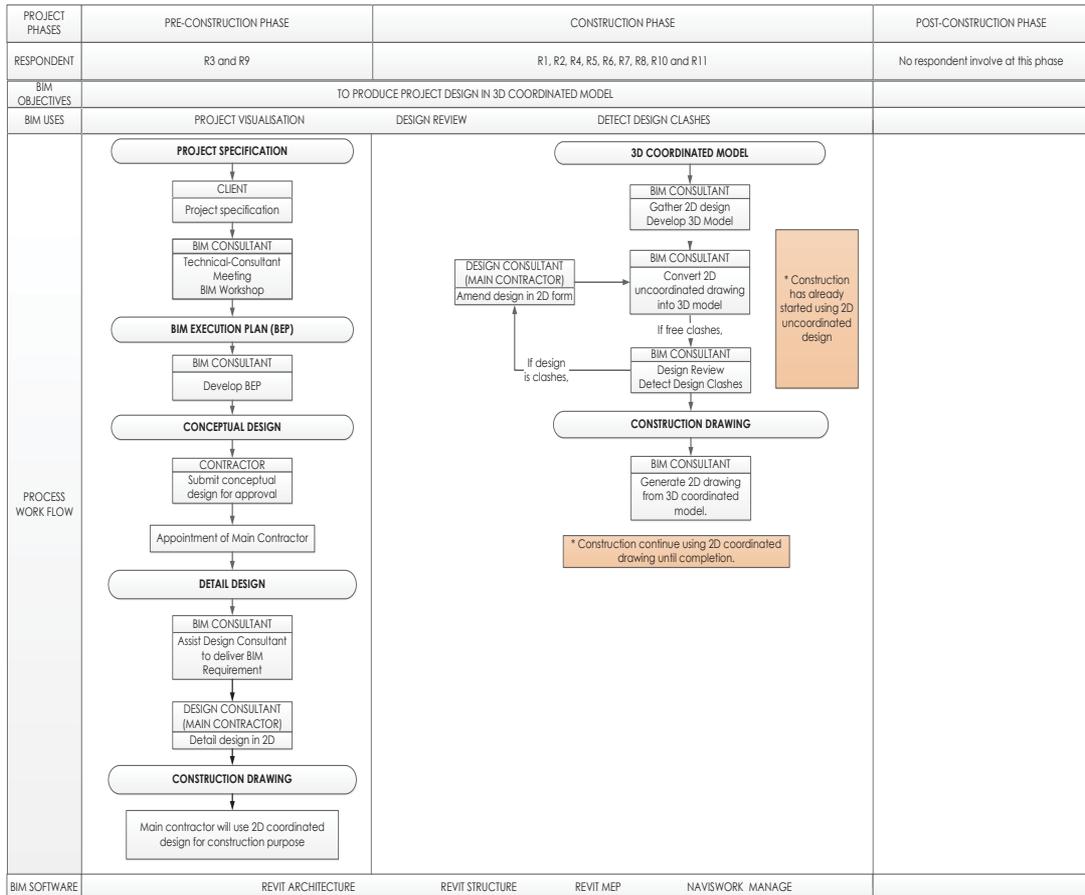


Figure 3. BIM Process in Design and build (D&B) Projects

The explanation of the figure is limited to the activities and process at pre-construction and construction phase. Hence, the explanation of the figure is categorised into two (2) phases as follows:

### Pre-Construction Phase

The figure is consists of respondents involved, project phases, BIM objectives, BIM uses, BIM process and BIM software. From the figure, the involvement of R3 and R11 started only at pre-construction phase. The processes involved at pre-construction phase are identification of project specification, development of BIM Execution Plan (BEP), development of conceptual design and detail design. R3 has been appointed by project client as a BIM consultant for the project. Meanwhile, R11 acted as a project client. The party that initiate to use BIM will set BIM objectives and BIM uses for the project.

The process of BIM occurred by the appointment of BIM consultant under client to assist in identification of BIM objectives and its uses. (Kensek, 2014) mentioned that the first step of BIM implementation is to define the modelling and shared the process requirements for the

project through the BIM uses. R3 stated that the appointment of BIM consultant by client was due to lack of knowledge and experience of client in using BIM in projects.

The objectives of using BIM in the project were to produce project design in 3D coordinated model and free from design clashes. From the objectives, BIM consultant will define BIM uses in more specific. Details of the objectives and uses will be stated in BEP. The implementation of BIM is normally lay down in BEP (Eadie et al., 2013; Kensek, 2014). BEP is a document to address an amount of information regarding responsibilities of construction players need to be contributed (Eadie et al., 2013; Kensek, 2014). Also, the BEP will be used as a supplementary agreement for the project.

Main contractor will start to develop conceptual design based on the requirement by the client. The conceptual design will be used to bidding the project. Only then, the client will appoint the main contractor for the project based on the conceptual design proposed by the main contractor.

At that point, by using client' specification, a detail design of the project will be executed by design consultant that fall under the main contractor. The respondents mentioned that the development of project' designed by design consultant was still in 2D due to the lack of capabilities of the design team in conquering BIM concept and BIM tools.

### ***Construction Phase***

Meanwhile, R1, R2, R4, R5, R6, R7, R8, R9, and R10 started to involve at construction phase. Those respondents were involved as architect, C&S engineer, contractor, and BIM consultant. The activities at construction phase were started by the development of 3D coordinated model and construction drawing. BIM consultant being appointed by main contractor will gather the 2D project design from design consultant under the main contractor. The purpose of collecting the 2D project design is to convert the design into 3D model.

The respondents stated that the purpose of developing 3D model must be referred to the BIM uses that are stated in the BEP. The development of 3D model must be a combination of information on 2D design (abstract of design concept) and 3D model (elaboration of design concept) (Eastman et al., 2011). After the development of 3D model, the project team including client could visualise the project as a whole before the completion (Forbes and Ahmed, 2010; Alaghbandrad et al., 2015).

The respondents mentioned that, BIM consultant used Revit Architecture and Revit Structure for converting 2D design into 3D model. Meanwhile, Naviswork Manage was used to conduct design analysis. Consequence to that, BIM consultant will get further information on project design from the design consultant. This is because the information on 2D design does not include sufficient information to fully describe 3D modelling. A BIM model must consists of sufficient information in order to conduct design analysis and other analysis such as site analysis, design performance, and energy analysis (Kim et al., 2016; Kokorus et al., 2016).

After the development of the 3D model, BIM consultant will conduct design review and detect design clashes. The purpose of design review was to improve the quality of design

information as a whole rather than component (Azhar, 2011) and to detect any possible design issues. As mentioned by (Eastman et al., 2011), trade and system coordination is a critical process among contractor. Hence, BIM consultant will conduct design analysis to detect design clashes for addressing any design clashes between different trades which are architecture design and C&S design.

When design clashes is detected, BIM consultant will suggest for design amendment to the design consultant. The respondents explain that the amendment of design was made in the form of 2D document by a design consultant due to the lack of capabilities in using BIM software. Then, BIM consultant will conduct a design review and detect design clashes until the design is free from clash. Only then, the 2D project design will be generated for construction purpose.

However, the respondents also highlighted that the use of BIM started when the construction activities has already started using 2D uncoordinated project design. They also added that the use of BIM is more as a trial project. Consequently, improper planning and implementation of BIM among construction players made it difficult and failed to get the benefit of using BIM (Bryde et al., 2013). Furthermore, construction players are still trying their best way to implement BIM in a project in order to reap the benefit (Monteiro and Martins, 2012). In contrast, there were respondents who started to use BIM by developing a proper BIM objectives and BIM uses before the major construction take place.

## **CONCLUSION AND FURTHER WORKS**

From the data collected, construction players have initiated the use of BIM in D&B projects. The purposes of using BIM are for project visualisation, to improve project design, and to detect design clashes. The implementations of BIM in D&B project were fulfilled at pre-construction and construction phase. Based on the BIM practices, the activities of BIM in D&B project is much similar with activities in conventional D&B project. The differences were by the activities done by BIM consultant in developing project design into 3D model for conducting design analysis.

The use of BIM software in managing project information is expected to improve the current practices of construction players in conventional project. Nevertheless, the process of developing project design still remains a traditional way which is in 2D document. This is due to the lack of capabilities of construction players in mastering the use of BIM software with the process involved. For that reason, a new designation related to BIM has been introduced and involved in the project to assist on BIM implementation, which is BIM consultant.

However, even there was an involvement of BIM consultant in the projects, the implementation of BIM by construction players were unable to reap the maximum benefit of BIM from the project. This is because the implementation of BIM only occurred when the construction has already take place. Nevertheless, proper planning and implementation of BIM at early phase of project could help them to get the benefit offered by BIM in improving construction project.

Further work will be focused on the potential improvement of BIM implementation that need for D&B projects. The improvement of the practices is vital to ensure that construction players could get BIM benefits, and thus the practices in construction could be improved.

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