Best practices of Building Information Modelling (BIM) implementation in design phase for construction project

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Abstract. Implementation of Building Information Modelling (BIM) was expected to bring improvement in current practices of Malaysian construction industry. In the design phase, there is a lack of a ready pool of skilled workers who are able to develop BIM strategic plan and effectively utilise it. These create boundaries for BIM nature in Malaysian construction industry specifically in the design phase to achieve its best practices. Therefore, the objectives of this research are to investigate the current practices of BIM implementation in the design phase as well as the best practices factors of BIM implementation in the design phase. The qualitative research approach is carried out through semi-structured interviews with the designers of different organisations which adopt BIM in the design phase. Data collection is analysed by executing content analysis method. From the findings, the best practices factors of BIM implementation in design phase such as the incentive for BIM training, formal approach to monitoring automated Level of Detailing (LOD), run a virtual meeting and improve Industry Foundation Class (IFC). Thus, best practices factors which lead to practices improvements in the design phase of project development which subsequently improves the implementation of BIM in the design phase of Malaysian construction industry.

1. Introduction
Malaysian construction industry’s project development is divided into three major stages, which are pre-construction stage, construction stage and post-construction stage [1]. These three stages also being called as a ‘project life cycle’ involving numerous workers, a list of activities, costs, and stakeholders. According to National Centre for Construction Education and Research (2008), there are three activities in pre-construction stage, which are project design, cost estimates and project scheduling while the actual construction work is carried out in construction stage and as in post-construction stage, final inspection, project administration, project close out and operating and facilities management are the activities involved. This research is focusing on pre-construction stage since it plays a critical role to commence the construction project. The first phase of pre-construction stage which is a design phase, its necessity to verify the design so that the project meets client’s requirements. Design challenges must have been resolved before the end of the final design stage. Furthermore, sufficient details must be provided with the drawings as well to allow accurate construction estimates and operating costs together with the construction schedule. On the other hand, in order to achieve success in the critical phase of the project which is a design phase, best practices of technology implementation is vital. Moreover, Malaysian Construction Industry Transformation Programme 2016-2020 (CITP) encourages the adoption of Building Information Modelling (BIM)
technology as a productivity enhancing tool which will change in the way the industries goes about designing a building and infrastructure as a third strategic thrust [2].

Building Information Modelling (BIM) is one of the technologies which represents the process of development and the use of a computer generated model to execute construction activities such as planning, designing, constructing and operation of a building in a virtual environment [3]. Thus, BIM plays its own roles in the design phase to bring the basic traditional method into the new emerging method by the use of 3D and 4D parametric authoring tools as object-based modelling software. BIM was introduced in Malaysian construction industry in 2007 by Public Work Department (PWD) and the implementation of BIM was expected to bring improvement in current practices of Malaysian construction industry. Switching from Computer-Aided Drafting (CAD) to Building Information Modelling (BIM) by the construction parties creates several challenges and benefits in the design phase, but yet, the benefits from BIM implementation outweigh the challenges [4]. BIM in Malaysian construction industry is still emerging but yet, it is currently practiced by developers. In addition, there are several challenges that limit the implementation of BIM in Malaysian construction industry focusing on the design phase which was driven by cost, market trends and organizational behaviours [5]. Even though BIM drives to benefits, there are still barriers towards implementing it and achieving those benefits, for example, ‘lack of competent staff to operate the software’ is the most significant barrier in contractor’s perspective [6]. Thus, the awareness of potential benefits of BIM implementation is vital and need to be strengthened by spreading the reason on why it should be implemented at its very best, overcoming the obstacles and optimizing its adoption in the design phase of project development.

There is a lack of skilled workers who are capable of developing BIM implementation strategic plan and effectively utilize BIM in the design phase [2]. The strategic plan involves the selection of BIM tools to carry out design development by considering the strengths and weaknesses. Besides, BIM usage guideline is also limited regarding Malaysian ways of working. Here, BIM can be challenging and there is no remedy to treat those challenges and transform it into potential benefits that the adopters might get. This will then give skepticism to the construction firms in implementing it at a very first phase of project development as well. Therefore, to ensure the best practices of BIM in Malaysian construction industry, it is crucial to spread the awareness of BIM advantages and inducements among all parties in this industry in order to improve the current practices of BIM implementation in the design phase. Several best practices are already identified, BIM training for example, but there is a need to find the key factor to ensure the continuous success of BIM training. Hence, this research is carried out to investigate the current practices of BIM implementation in the design phase and the best practices factors of BIM implementation in the design phase.

2. BIM implementation in design phase

Building Information Modelling (BIM) is used in diverse ways in project development by the key players of the construction industry. The architect, for example, implements BIM to produce architectural drawings, followed by engineers producing structural or energy data management and contractor develop coordination model of the building. Concept design does not only provides a framework of design in terms of its structure, spatial layout, and environmental condition, but also the cost estimates, building practices and the aesthetic considerations as well [7]. Furthermore, BIM does provide several tools to assist designers that involve in design phase which is Autodesk Revit that composed of Revit Architectural, Revit Structural, Revit MEP as well as Tekla and Bentley that currently practices in Malaysian construction industry [8]. In brief, there are various types of BIM tools available for designers to develop project designs. However, it is not necessarily for companies or firms to practice only one type of BIM tools for their designers. This is due to the differences involving the design team in terms of skills, preferences and desired outputs [9]. Hence, monitoring is needed to ensure the designers achieves what has been expected from them in term of work quality and productivity if the whole team design practices different BIM tools.

In order to increase the practices of Building Information Modelling (BIM) in the design phase, it is important to address the potential challenges of its implementation. From challenges identification, solutions and initiatives could be addressed afterward. Eventually, from the solutions of those
challenges, the benefits of BIM implementation including its awareness will efficiently spread among the parties in the construction industry. In brief, there are several challenges highlighted by various researchers focusing on BIM practices in the design phase. The BIM implementation challenges in design phase such as changes in practices, BIM disrupts established design workflow, requires skilled design team, designers preferences, time constraints, and integrated use of expert models [7][10][5][11][12]. Generally, it involves design teams with other stakeholders such as contractor and sub-contractors, this is where BIM implementation comes to its limits. However, those challenges are quite needed for the government, Malaysian government, for instance, to enhance initiatives in order to encourage the use of BIM implementation in Malaysian construction industry. Without challenges and problems, there will be no lessons to learn and improve the current practices of BIM implementation in the design phase.

Building Information Modelling (BIM) offers huge benefits to the adopters, especially in architectural, engineering and construction (AEC) sector. However, those benefits only could be fully achieved if there are proper practices implements by the adopters. Without best practices of BIM, still, it is hard to exploit the benefits from the implementation. Hence, it is important to execute BIM implementation best practices strategic plan to ensure the works are clearly defined and understood which makes BIM as a useful tool to develop construction projects [13]. Also, the best practices factors of BIM implementation in the design phase is crucial. Best practices factors are basically the idea of how to improve current practices. Hence, in the design phase of construction project lifecycle, it is beneficial for the design team as well as other stakeholders to formulate the best practices factors of BIM implementation to obtain the benefits that BIM might offers. From the designers’ perspectives, more ‘3D Building Product Manufacturer-specific content’ is favourable as an improvement [14]. Thus, regardless of how beneficial BIM is for designers, without a proper plan to its best practices, there are still several limitations to earn those benefits. The best practices of BIM will then drive to a great success of construction project development and brings the construction industry to the new high level.

3. Methodology
The research design refers to the strategy to integrate the different components of the research in a coherent and logical way. This will ensure the effectiveness of addressing research issues towards achieving research objectives. According to [15], a good research design is when all the components work harmoniously together, promotes efficient and successful operation towards achieving objectives, while poor research design, on the other hand, leads to poor operation or failure. Meanwhile, according to [16], research designs are types of inquiry within the qualitative analysis, quantitative analysis and mixed methods approaches that provide specific direction for research procedures. Hence, this research is conducted by using qualitative approach by using interview questions. The collection of primary data involves the interviews from key players in the construction industry that experienced BIM implementation in the design phase. The secondary data for this research involved literature review covers the current practices of BIM implementation in the design phase and best practices factors. The interview is conducted during respondent’s working hours. It is from 10am to 4pm during weekdays. The duration of each interview is basically varied among the respondents. In brief, the interviews are between 40 minutes minimum until 2 hours maximum depends on the respondent’s answers, elaborations and also personal thoughts and judgments. After all, the findings from interviews with the respondents do satisfied data collection requirements for this research.

The target population for this research is the company that implements Building Information Modelling (BIM) in the design phase for their past project, current projects and upcoming projects as well. According to the Chief Executive of Construction Industry Development Board in 2014, only 10% of construction industry key players adopt BIM for their projects, and until 2014 only 20 projects were reported in accordance with the implementation of BIM [17]. Apart from that, several developers, contractor, and consultant that implements BIM has been identified as part of this research population which is located in Selangor and Wilayah Persekutuan Kuala Lumpur. A semi-structured interview is the main instrument for this research where the respondents have to answer open-ended
questions. The set of question for the interview is the composition of the core question with other associated questions [18]. The target respondents are among designers which are engineer and architect based on their contribution in implementing BIM in the design phase. As a matter of fact, semi-structured interviews is suitable in order to fully understand the respondent’s point of view regarding the current issues related to BIM implementation in the construction industry where it is not just limited to the questions itself. Thus, broad information and justification can be obtained from the respondents. In brief, the method in data analysis for this research is content analysis. Content analysis is a research technique used to interpret textual information or it is called qualitative-interpretative since this research performs interviews as primary data [19]. Meanwhile, according to [20], content analysis is the method of subjective interpretation through a systematic coding process. Thus, content analysis helps in structuring the information from various sources and perspectives as well. Hence, by executing content analysis, it will interpret the information from recorded interviews for further analysis with secondary data which is a literature review.

4. Results and discussion

4.1 Respondent’s background

In this sub-topic, all the respondents’ background in construction industry specifically on their contribution in BIM is identified. The selection of respondents involves consultant firm, developer, contractor and local authority by targeting the designer in that organization. Hence, Table 4.1 indicates the respondents’ background which participated in this research. In brief, the selection of respondents for this research is based on their academic qualification, experiences in the construction industry as well as experiences in BIM during design development phase. Apart from that, the collected data and information given by the respondents are precise and complementary with the objectives of this research. Hence, the selection of respondents for this research is suitable in order to achieve the research aim and objectives.

Table 4.1. Respondent’s background.

| Respondent | Types of organisation | Position | Experience in construction industry | Experience in implementing BIM |
|------------|----------------------|----------|-------------------------------------|--------------------------------|
| R1         | Developer            | Architect | 8 years                            | 4 years                        |
| R2         | Local Authority      | Chief Assistant Director Architect | 15 years | 9 years |
| R3         | Consultant           | BIM Coordinator (Structural-based) | 10 years | 6 years |
| R4         | Contractor           | BIM Executive (Structural-based) | 2 years | 2 years |
| R5         | Developer            | Senior Executive Building Technology | 20 years | 8 years |

4.2 Current practices of BIM implementation in design stage

Table 4.2 below shows the current practices of BIM implementation in design phase based on the summary of findings from collected data through semi-structured interviews with selected respondents. It consists of strengths and weaknesses of BIM tools, BIM challenges in the design phase as well as benefits of BIM implementation in the design phase.
Table 4.2. Current practices of BIM implementation in design phase.

| Current practices of BIM implementation in design phase | Description |
|--------------------------------------------------------|-------------|
| (a) Strengths and Weaknesses of BIM Tools               |             |
| • Autodesk Revit; Revit Architecture, Revit Structure and Revit MEP | **Strengths**       |
| • ArchiCAD                                               | • Lowest initial cost |
| • Bentley                                                | • Concurrent operation |
| • Tekla Structure                                       | • Great coordination |
| • Great coordination                                    | **Weaknesses**     |
| • Large object libraries or families                     | • System lagging |
| • Bentley                                                | • Poor sharing capability |
| • Great coordination                                    | • Poor sharing capability |
| • Great coordination                                    |             |
| (b) BIM Challenges in Design Phase                      |             |
| • Before designing                                      | **Challenges**     |
| • During designing                                      | • Collaboration and teaming |
| • After designing                                       | • Unenthusiastic stakeholders |
| • Unclear BIM standards                                 | • Time constraint |
| • Risk increase                                         | • Risk increase |
| • Unclear benefits                                      | **Benefits**       |
| • Reduce error                                          | • More client’s input |
| • Fast fabrication drawing                              | • Consistent view |
| • Great coordination                                    | • Faster decision making |
| • LEED compliance                                       | • Reduce manpower |
| • Predict environmental performance                     | • Less time and cost |
| • More client’s input                                   |             |
| • Consistent view                                       |             |
| • Faster decision making                                |             |
| • Reduce manpower                                       |             |
| • Less time and cost                                    |             |

According to the respondents, the strengths of BIM tools can be divided into four (4) categories; lowest initial cost for Autodesk Revit; concurrent operation for Autodesk Revit; large object libraries (families) for ArchiCAD; and great coordination for Autodesk Revit, Bentley, and Tekla Structure. Meanwhile, the weaknesses of BIM tools are system lagging for Autodesk Revit and poor sharing capability for ArchiCAD and Bentley. All those categories are complementary with previous research [6][7]. It is important to discover each BIM tools strengths and weaknesses in order to give a clear figure to the designers in a construction project team of what they actually embrace. The respondents agreed that it helps to improve the decision making of which BIM tool is appropriate to be implemented by the designers of all trades. Equally important, the information gathered can be used as a result of a survey for the BIM tools’ developers as well in order to develop a plan to improve their products.

Next, the challenges of BIM implementation in the design phase are also being identified. The respondents for this research claimed that challenges before designing in BIM process is collaboration and teaming, unenthusiastic stakeholders and unclear BIM standards. Meanwhile, the challenges of designing in BIM process are time constraint to develop a model and increase the risk of disputes. Lastly, unclear benefits are the challenge of BIM implementation after designing. All of the respondents agreed that those challenges will affect the performance of design team in a construction project. Hence, the design team needs to develop their own strategic plan to solve the challenges when it comes to BIM implementation in design phase because after all, designing is a crucial phase before
commencing actual construction works. Any disputes during designing will affect the whole project performance and decrease the effectiveness of BIM implementation itself. Once the challenges are fully overcome by the construction key players, the benefits of BIM implementation in the design phase can be fully exploited.

Lastly, according to respondents for this research, there are three (3) classifications of BIM benefits in design phase: clash detection which contributes to the reduction of error, fast fabrication drawing, and great coordination among designers; high quality of BIM model output since it is certified with LEED compliance and capable of predicting environmental performance; and contributes to high productivity since it allows more client outputs during designing, consistent models view, faster decision making, reduce manpower and require less time and cost. The first research objective is also achieved since the respondents agreed that the advantages gained in the use of BIM in the design phase of the construction project will be able to increase the implementation awareness of BIM in Malaysian construction industry. Also, there is a need to identify the best practices factors of BIM implementation in the design phase in order to promote its benefits and spread the awareness of BIM potentials to the construction industry.

4.3 Best practices of Building Information Modelling (BIM) implementation in design phase

From current practices of Building Information Modelling (BIM) implementation, there are several improper techniques which create boundaries to achieve its best practices in the design phase. In order to make BIM as a useful tool to develop construction projects, it is important to execute BIM implementation’s best practices strategic plan which ensures the works to be clearly defined and understood by the adopters [13]. When it comes to the formulation of the strategic plan to achieve best practices in BIM implementation during design development, all of the respondents in this research claimed that it is more appropriate if all the stakeholders in project development are involved. ‘Top-down and bottom-up management’ would be the keys to encourage the complicity of the stakeholders to develop a strategic plan towards achieving best practices in BIM implementation. Table 4.3 below shows the best practices factors of BIM implementation in design phase based on the summary of findings which consider findings from literature as well as from collected data through semi-structured interviews with selected respondents. It consists of BIM training among designers, tactical design development, enhances effective collaboration in design review and capabilities of maintaining exchanged data.

| Best practices’ factors of BIM implementation in design phase | Description |
|-------------------------------------------------------------|-------------|
| 1 | **BIM training among designers**<br>Best practice’s factor: Provide incentive for designers to undergo training process | |
| 2 | **Tactical design development**<br>Best practice’s factor: Provide formal approach to monitor level of detailing (LOD) in BIM feature | |
| 3 | **Enhance effective collaboration in design review process**<br>Best practice’s factor: Carry out virtual meeting in conducting design review process | |
| 4 | **Capabilities of maintaining exchanged data**<br>Best practice’s factor: Improve Industry Foundation Class (IFC) compatibility | |

From the findings of this research, there are four (4) best practices factors of BIM implementation in design phase; provide incentive for the designers to go to a BIM training, provide a formal approach to monitor automated Level of Detailing (LOD) in BIM feature during tactical design development, run a virtual meeting for enhancing effective collaboration in design review process; and lastly, improve Industry Foundation Class (IFC) to support the capabilities of maintaining exchanged data among designers of different trades. From the
interviews, the best practices factors that have been identified covers the construction team management and planning, designer’s scope of work and the technology as well. People, process, and technology are interrelated in order to develop a strategic plan towards achieving best practices of BIM in design phase through its identified best practices factors. In brief, BIM urges the adopters to develop a strategic plan on how to make it beneficial for all stakeholders to ensure it is best practice. The strategic plan needs to include people, process, and technology, since BIM changes the whole design process through its broad types of technology and people (construction stakeholders), needs to deal with the changes. It is basically the factors on how to make the best practices effective. Certainly, those best practices are also supported by previous research [6][8][9][14].

5. Conclusion
In conclusion, the current practices of BIM tools implementation in the design stage are Autodesk Revit (Revit Architecture, Revit structure and Revit MEP), ArchiCAD, Bentley and Tekla Structure. All the tools have specific challenges and weakness in the implementation of BIM in the design stage. The challenges of BIM implementation in the design phase are also being identified such as before designing (collaboration and teaming, unenthusiastic stakeholders and unclear BIM standards), during designing (time constraint to develop a model and increase the risk of disputes) and after designing is unclear benefits. Furthermore, there are three (3) classifications of BIM benefits in design phase; clash detection which contributes to the reduction of error, fast fabrication drawing, and great coordination among designers; high quality of BIM model output since it is certified with LEED compliance and capable of predicting environmental performance; and contributes to high productivity since it allows more client outputs during designing, consistent models view, faster decision making, reduce manpower and require less time and cost. There are four (4) best practice’s factors of BIM implementation in design phase; provide incentive for the designers to go to a BIM training, provide a formal approach to monitor automated Level of Detailing (LOD) in BIM feature during tactical design development, run a virtual meeting for enhancing effective collaboration in design review process; and lastly, improve Industry Foundation Class (IFC) to support the capabilities of maintaining exchanged data among designers of different trades. Thus, by identification of best practices factors of BIM implementation in the design phase will bring improvements in BIM current practices during design development. This will then accelerate the percentage of BIM implementation in Malaysian construction industry through the awareness of how BIM is beneficial to the adopters once it is practiced at its very best.

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