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Study of BIM Tools Implementation among Contractors During Project Construction Phase in Construction Industry

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Abstract: Building Information Modelling (BIM) provides significant benefits to the contractors. However, BIM tools in construction phase projects seem not fully been implemented and rarely used by contractors. This is because of the certain problem faced by contractors, which are interoperability, high implementation cost, lack of knowledge by site workers about BIM tools technologies, and other consultants not using BIM tools. Therefore, the purpose of this research to study what is the current practices, challenges and benefits of BIM tools implementation among contractors at the construction phase. The literature review was carried out to discover BIM tools implementation among contractors during the construction phase. Qualitative research methodology conducted by interviews with the contractors which currently involved and have been involved in projects using BIM tools for residential and commercial projects in Malaysia. All data obtained from the interviews were analyzed and carried out by using content analysis. Therefore, both data from the literature review and the interviews were used to complete this research. The contractor realizes the importance of using BIM tools during the construction phase such as Revit and Navisworks that assist them in the construction site. The awareness of the importance of using BIM tools and cost becomes a major challenge for the contractors to implement BIM tools during the construction phase. This research needs to know how BIM tools can be fully implemented during construction, to help the contractor achieve several advantages provided in the construction phase by the implementation of BIM tools.

Keywords: BIM, Construction phase, Contractor, Tool

1. Introduction

BIM tools have the ability to handle building projects from the pre-construction stage to the post-construction stage (Levy, 2010; Eastman *et al.*, 2011). In several forms and functions, BIM tools have been implemented. The software includes Revit, Tekla, Bentley, Autodesk, Vico, and Cost X. Each

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tool has its own functions and is used to handle various tasks in construction projects (Francois, 2012). During the construction phase of the building lifecycle, BIM makes available at the same time information on the quality, timing, and cost of the building. It enables the builder to update progress and compare it with plans, make changes in prediction, schedule, and time for remaining work, and connect with related project participants immediately. The key work in the construction process is the delivery of projects, the commissioning of equipment and structures, the approval of the complete materials, and the planning for the transfer of property. One of the main advantages of BIM tools during building is a substantial reduction in rework (Aranda-Mena *et al.*, 2009). The building model is built in contractor and objects are allocated recipes that describe the tasks and resources required to build or produce them, quantities and costs are measured quantity surveyor, schedule activities are described and scheduled using balance techniques in control, and then 4D construction simulation is visualized in Presenter. BIM tools have also increased quality and enabled the identification of defects during the design process, and the probability of any major on-site issues is low. Errors, disputes, and on-site change orders can be handled more easily by using BIM since there is no need for time-consuming paper transactions. Both of these benefits combined would make the building process quicker and easier, reduce costs, and minimize the risk of legal disputes (Eastman *et al.*, 2008). Other than that, the implementation of BIM tools can enable the contractor to manage safety in the construction process. The construction process involves many threats. The safety measures in the project, especially in Malaysia, are questionable. Protection has earned a great deal of concern from the participants, but the business climate has been known to be a dangerous place to operate.

Interoperability is one of the key setbacks for the implementation of BIM tools during the construction process. All data cannot be compatible with the BIM software used by the general contractors because the consultants used various types of BIM tools that generate several types of data files. From a technological point of view, interoperability limitations are primarily related to data sharing formats and software systems used in the project (Alshawi & Ingirige, 2003). Second is BIM tools require very high implementation costs. The cost involves purchasing software and hardware, hired BIM experts, and employee training. Another factor is the lack of knowledge of BIM-related site workers, which has become another issue with the introduction of BIM tools during the construction process. The issue is that site workers do not have access to this information that is accessible in a BIM dataset (Van Berlo & Natrop, 2015). In addition, the implementation of BIM tools among contractors during the construction phase cannot occur if other consultants, such as architectures, engineers, and quantity surveyors, do not use BIM tools. Design-Bid-Build (DBB) is a project management system where the owner has a different contract with the designer and the contractors. This research is therefore carried out in order to study the potential of the implementation of BIM tools among contractors during the construction process. Since BIM tools were applied during the construction process, construction issues could be minimized during the construction phase. Therefore, the objectives of this paper are to study the current practices, identify the challenges, and determine the benefits of building information modeling (BIM) tools implementation among contractors at the construction phase.

2. Literature Review

2.1 BIM Implementation in Construction Phase

Construction industry a major industry that contributes to the economy of Malaysia. Construction industries are often seen as the engine of economic growth, especially in developing economies. In building and maintaining buildings and facilities the industry should enable and effectively consume locally manufactured material and labour in order to promote local jobs and increase economic efficiency (Anaman and Osei-Amponsah, 2007). The contractor designs manufacture and install the equipment of the project during the construction phase. The activities are carried out in compliance

with the design phase's plans and requirements. The facilities and equipment will be installed and evaluated at the start-up process after completion. During a building project, multiple parties take part in project completion. The parties may be from the private or public sectors. The main parties are the owner and client, the architect is for the project design and engineers calculate the structural work, the quantity surveyor for calculating the cost of the project, and the general contractor to handle the construction project.

Implementation of BIM technology will contribute to greater construction industry efficiencies through increased collaboration between different project participants, fewer collisions, and repeat work on corrections and adjustments (Ford *et al.*, 1995). The building information model describes geometry, spatial relations, geographical information, quantities and properties of construction elements, cost estimates, material inventories, and project schedules. The model can be used to illustrate the entire life cycle of the building (Dikbas *et al.*, 2004). Building information modeling (BIM) systems on shared digital databases, handle changes in any aspect of a database, synchronize changes in every other way and gather and store knowledge from other industries to reuse (Autodesk, 2002).

2.2 Current Practices of BIM Tools Implementation

There are four common BIM tools used by contractors for BIM tools implementation during the construction phase which are Navisworks, Revit, Cost X, and Synchro (refer to Table 1).

Table 1: Current practices of BIM implementation among the contactor

Current Practices of BIM tools	Description
Naviswork	A high-tech 3D geometry engine that allows the composite virtual projects model to be evaluated, simulated, and analyzed in an immersive manner, to check and predict design, and function (Joseph and Bhat, 2017).
Revit	Its resemblance to applications such as AutoCAD or SketchUp occurs in its ability to create a virtual three-dimensional building model. However, while AutoCAD and SketchUp avoid simulating the geometry of a building, Revit allows the elements inside a building model to be parametrically connected, the components of such a model are defined and characterized by adjustable parameters (Christenson and Mike, 2008).
Vico Office	The Vico Office has recently allowed combinations to be used more effectively to allow wider use of BIM applications, tools for design, and cost estimates. The time and cost planning interface of step-by-step data from BIM on an actual construction work using the Vico Office application (Pučko, Nataša & Klanšek, 2014).
Synchro	Synchro 4D is unique in automating the BIM model and updating the 4D construction plan. Reduce costs with robust resource management and monitor the planned quantity, project or contractor value, or critical paths versus installed quantity. Leading 4D progress appraisal meetings as a central knowledge center for all stakeholders to ensure open, collaborative, and productive preparation and decision-making (Eastman *et al.*, 2011).

2.3 Challenges of BIM Tools Implementation

There are five main challenges faced by contractors for BIM tools implementation during the construction phase which are cost, training, ownership, resistance to change, and interoperability (refer to Table 2).

Table 2: Challenges of BIM implementation among the contactor

Challenges	Description
Cost	A significant initial investment for upgrading software, hardware and training employees is required to implement BIM in the construction industry (Baba, 2010).
Training	Lack of train is one of the major obstacles to the effective implementation of BIM. It also affected BIM adoption decision-making (McGraw-Hill, 2009).
Ownership	The ownership problem cannot be addressed by a single rule but depends on the workers and the amount to which they provide information for each project (Azhar, 2008).
Resistance to Change	The problem comes when people oppose improving better, for them using BIM means an expert is needed to apply the software in their company (Smith and Tardiff, 2009).
Interoperability	This interoperability issue emerged when a single software tool was built to meet the needs of multiple fields (Thompson and Miner, 2006).

2.4 Benefits of BIM Tools Implementation

Implementation of BIM tools during the construction phase can improve in terms of visualization, reduction of design errors using clash detection, construction analysis and planning, integration with cost and schedule control and other management functions, use for offsite fabrication, and use of BIM on-site for verification, guidance, and tracking of construction activities (refer Table 3).

Table 3: Benefits of BIM implementation among the contactor

Benefits of BIM Tools	Description
Visualization	Visualization tools include various visual simulations, such as digital images, animated videos, 360-degree panoramas, augmented reality solutions, and immersive virtual passage around the building in the very early stages of the creation of concepts. This is very beneficial during the project bidding stage, where the developer and construction manager can easily share the BIM idea with a variety of participating individuals (Veld, 2015).
Reduction of design errors using clash detection	BIM-based clash detection offers many benefits in contrast to conventional 2D coordination approaches such as light table overlays or basic 3D controls. 3D clash detection relies on 3D geometry models for identifying geometric entities often return a large number of meaning-

	less clashes (Raut *et al.*, 2017).
Construction analysis and planning	These systems demonstrate the relation between the activities and the estimation of important paths and floating value, which enhance planning in a project, enables the planners to plan on a location to enable workers to work repeatedly in different locations (Eastman *et al.*, 2008).
Integration with cost and schedule control and other management functions	The Estimating and 5D modeling use of BIM entails using the data stored in the BIM to extract information and transfer that information into construction estimates. These estimates can be updated rapidly based on information obtained from the BIM model as the design progresses or changes occur (Kulkrani and Mhetar, 2017).
Use for offsite fabrication	The proper use and integration into structured building components or capacities of building components can accurately represent the geometry, activity, and properties of specific building components and can be made available digitally (Nawari, 2012).

3. Research Methodology

This research will be conduct used qualitative methods are a variety of research styles that rely on unstructured and non-numerical methods of data analysis. Evidence can be collected by the researcher in field notes in the course of observations or interviews, in natural environments, or interviews and documents, as sound or video recordings.

3.1 Research Design

This research was conducted using a literature review and qualitative method with an interview session. The methodology to obtain information in this study is shown in Figure 1.

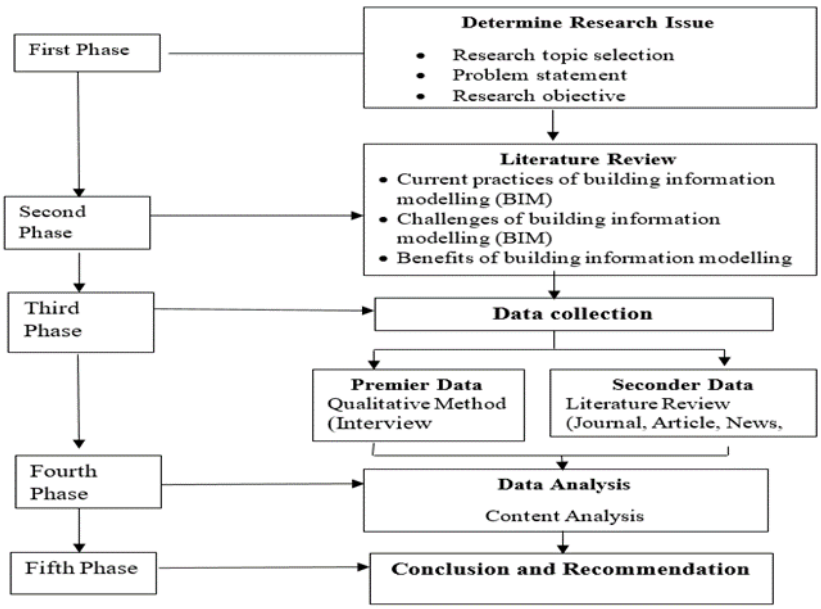

Figure 1: Research Methodology Process

3.2 Data Collection

This data collection stage is important in order to get accurate data and ensure that the data are from strong evidence resources. Resources from primary data and secondary data are being used in order to achieve the objective of this research.

(a) Primary Data

The approach chosen was an interview method with the respondent as regards this research. This approach also served to achieve research objectives that identify current practices, challenges, and benefits of BIM implementation among contractors at construction. This study was focus to understand more about the implementation of BIM tools among contractors during the construction phase and obtaining an expert opinion about this implementation in this construction field. The qualitative method is therefore the most effective approach to this analysis.

(b) Secondary Data

Secondary data is the data, which can be collected by reading and analyzing literature such as papers, documents, past studies, and any relevant facts. The data collected from this analysis will be analyzed and used for the summary and preparation of questions from the interview. The search and gathering of data from all available sources and guidance for achieving the study goal is the collection of secondary information.

3.3 Data Analysis

Data analysis will briefly describe the step and method for analyzing the data. The method includes a description of the textual data obtained. The researcher expects to obtain a response from the research question and to gain accurate information on the current practices, challenges, and benefits of BIM implementation among contractors at the construction phase. Content analysis is used for this data analysis process. Data obtained during the interview will be analyzed using Microsoft Word 2013. The researcher expects to achieve the purpose of this research by analyzing the results. This study is therefore intended to provide a greater awareness of the implementation of BIM tools among contractors at the construction phase.

4. Results and Discussion

4.1 Respondent Background

Respondents are important for this qualitative approach to ensure that all data obtained from the respondent is accurate and to answer the question based on the respondent's work experience. Respondent for this research is the contractor that has experience using BIM tools. Table 4 shows the respondent's background, which involved in this study.

Table 4: Respondent Background

Respondent	Organization	Position	Experience in BIM Technology
Respondent 1 (R1)	Company A	Project/Design Architect	1 Year
Respondent 2 (R2)	Company B	Assistant BIM Manager	3 Years
Respondent 3 (R3)	Company C	Managing Director	3 Years

4.2 Current Practices of Building Information Modelling (BIM) Tools Implementation among Contractors at Construction Phase

Table 5: Summary of current practices of BIM tools implementation among contractors

BIM Tools	Question	R1	R2	R3
Revit	Revit used at the construction phase when other consultants still using the traditional 2D drawing	The contractor does not implement BIM tools in their practice is due to costing to subscription for software provider and having skilled BIM draughtsman might not be viable for their project cost.	The contractor has the responsibility to turn 2D into 3D and proceed for clash coordination	Not be a problem because the contractor will create the 3D model using Revit based on traditional 2D drawing
	Data file receives from the other consultant cannot support by the Revit	Revit files can be exported to AutoCAD, which is widely practiced among consultants. It will not be a problem for consultants in this matter.	Revit can support most of the software in the market including pdf	I have never faced this problem before, but I know Revit software can support any type of file.
	Accurateness of 3D models in giving the information to the contractor	Accurate and all info in a single project can be accurate, coexist, and consistent with each other since it is based on a single model	Depends on the model quality	Very accurate, because we can see the virtual of the building model before construct
Navisworks	Skill and knowledge needed for a contractor that has the intention to implement the use of Navisworks for the construction phase		Skill to use Navisworks and turns the idea of design into construction	
	Reduce the error during the construction phase in terms of cost, time, and quality		Reduce clash, improve construction quality, reduce rework and time of delay	

BIM Tools	Question	R1	R2	R3
	Navisworks contribute advantages if these BIM tools implement during the construction phase?		Clash coordination, and have a clearer picture for the constructor	

As shown in Table 5, the answer is given by the respondents about using Revit as current practices of BIM tools implementation among contractors at the construction phase. Here is the statement was given by the respondent:

"In my experience, Revit files can be exported to AutoCAD which is widely practice among consultants. It will not be a problem for consultants in this matter" (R1)

"So far, Revit can support most of the software in the market including pdf" (R2)

"I have never faced with this problem before, but I know Revit software can support any type of file" (R3)

All the respondents agreed Autodesk Revit can support many types of files and these BIM tools are easy to receive in many types of format. Revit allows elements within a building model to be parametrically linked the components of such a model are defined and characterized by adjustable parameters (Christenson and Mike, 2008).

4.3 Challenges of BIM Tools Implementation among Contractors at Construction Phase

Table 6: Summary of challenges of BIM tools implementation among contractors

Challenge	Question	R1	R2	R3
Cost	Cost becomes the major barrier for the contractor that what to implement BIM tools during the construction phase	Contractors are not necessary to have BIM tools in small scale projects due to costing and time unless it is a big scale projects such as mega complex or high rise which contractors may have there in house BIM draughtsman to interpret the drawings to speed up the construction process	The high initial cost is part of the process to implement BIM, Costing is not the major problems, awareness is	The software subscription is very expensive
	BIM tools required high cost for the	Contractors did not implement BIM tools in their	Manpower, training, software, and hardware	Training required, maintenance of the hardware and the

Challenge	Question	R1	R2	R3
	contractor that wants to implement during the construction phase	practice is due to costing to subscription for software provider and having skilled BIM draughtsman might not be viable for their project cost		software subscription
Training	The contractor should go for training first such as BIM module training by myBIM Malaysia before the contractor want to implement the BIM tools during the construction	Improve construction productivity and efficiency, as it could prevent wastage, time-wasting, and clash-free design in construction	Improve the model quality and accuracy before delivering to the construction site	Improve skills and knowledge about the tools
	Type of training does the construction worker involved in any construction project using BIM tools during the construction phase require	To provide skill, abilities, and expertise in BIM software. Especially skills in interpreting drawings using BIM tools	Construction workers not necessary to have training in BIM, after clash coordination in Revit, we still can export the model into 2D CAD for workers to construct	They still using 2D traditional drawing on-site reference, no training required
Ownership	Ownership issues between the Contractor, client, and consultant can be solved	No answer	The contractor will produce a coordinated drawing for the consultant and client to approve	Provide BIM data access to all
	Implementation of BIM tools can happen in the construction phase if the Contractor did not have access to the BIM data provided by other consultants	It will have no issues as BIM tools can export drawings to contractors	Have to establish BIM to access	No answer
Resistance to Change	Contractor afraid to take the risk on	Costing issues and unnecessary to implement in	Not afraid, but reluctant if the awareness is not	They are too comfortable with the traditional

Challenge	Question	R1	R2	R3
	implementation of BIM tools during the construction phase even though it will bring many benefits to themselves	their construction process depending on the scale of the project where BIM tools may not benefit much to the process	there.	method
	The main reason for the low percentage of BIM tools implantation among the contractor during the construction phase	Cost for subscription from software provider and having skilled BIM draughtsman might not be viable for their project cost.	The awareness BIM towards the construction industry	Lack of exposure to the benefits of using BIM tools
Interoperability	Lack of interoperability can become a barrier to the contractor that wants to implement BIM tools at the construction phase	No longer become an issue because BIM provide IFC that allow other tools to import the data	Most of the software has resolved the problems. Meanwhile, we can state in the contract that the software using in the delivery message	This currently not becomes a barrier because the contractor can use IFC (Industry Foundation Classes) for open BIM data exchange. It used for transferring model data between different BIM software packages
	The solution if the contractor receives a file that not supported by the BIM tools	Request export drawings to another format from consultants	These problems will resolve during the tender stage. Standardized	Request IFC data

As shown in Table 6, the answer is given by the respondents about training challenges of BIM tools implementation among contractors at the construction phase. Here is the statement was given by the respondent:

"In the whole scenario, It could greatly improve construction productivity and efficiency, as it could prevent wastage, time-wasting and clash-free design in construction" (R1)

"Improve the model quality and accuracy before delivering to construction site" (R2)

"Improve skills and knowledge about the tools" (R3)

All the respondents agreed training is one of the challenges of BIM tools implementation among the contractors at the construction phase and the state training in using BIM tools will improve the quality of the model and it could improve skills, knowledge, and productivity during the construction

phase. Based on previous research, lack of train is one of the major obstacles to the effective implementation of BIM. It also affected BIM adoption decision-making (McGraw-Hill, 2009).

4.4 Benefits of BIM Tools Implementation among Contractors at Construction Phase

Table 7: Summary of benefits of BIM tools implementation among contractors

Benefit	Question	R1	R2	R3
Visualization	Visualization produce by the BIM tools can assist the contractor during the construction phase	Can provide more information based on a single model	Have clearer pictures and resolve constructability during the construction stage.	Produce accurate info and detail before start the project
	Visualization is important to the contractor in improving the schedule, analysis, and cost during the construction phase	Allow contractors to have a better understanding of designs and it could save time on miscommunication or misunderstanding	Many unforeseen issues will resolve before construction	Can analyze any unnecessary work and clash before start the project
Reduction of Design Errors Using Clash Detection	BIM tools feature clash detection can become an important factor to reduce project cost and time	Have a better understanding of designs and could save time on miscommunication or misunderstanding	Reduce reworks, improve constructability, and redesign during the construction stage.	Early clash detection can reduce rework, saving cost and time
	Various types of clash detection and what is important separating each type of clash	No answer	There are hard clashes, soft clashes, and time clashes. Mainly is providing the space required for servicing and maintenance in the future.	Help in project scheduling and reduces the risk of human error during model inspections.
Construction Analysis and Planning	Create an effective schedule for the contractor and help on the project construction analysis and planning	No answer	4D simulation. Have the idea of construction sequence before projects start	BIM offers a 4D model that allow the contractor to merge the model and the schedule become more effective
	Analysis and planning using BIM tools	No answer	Reduce reworks and redesign during the	It helps the contractor to save cost and time

Benefit	Question	R1	R2	R3
	during the construction phase can assist the contractor		construction stage	
Integration with Cost and Schedule Control and Other Management Functions	Integration of cost and schedule can happen using BIM tools	No answer	BIM can simulate and export quantities for Costing.	Using 5D features that can integrate visual, schedule, and cost
	Project cost control can easily monitor by using BIM tools during the construction phase	No answer	Can be monitor and construct through coordinated drawing, reduce reworks and wastage	More precise and accurate cost estimates. The automation of the take-off process allows for faster analysis of the building costs and variants.
Use for Offsite Fabrication	BIM tools can help the contractor with offsite fabrication	No answer	Size, length, and quantities can be determined in an earlier stage.	Due to more on-site controllable equipment and energy savings
	Automated techniques can relate to BIM tools	No answer	Many ideas of design can be determined and visualize earlier and improve constructability	Give a clear visualization and reduce error on site

The question regarding why visualization is important to the contractor in improving the schedule, analysis, and cost during the construction phase are also been asked during the interview session as shown in Table 7. The responses given by the respondents are as follows.

"It allows contractors to have a better understanding in designs and it could save time on miscommunication or misunderstanding. Greatly improved due to clash-free design" (R1)

"Many unforeseen issues will resolve before construction" (R2)

"Can analyses any unnecessary work and clash before start the project" (R3)

Clearly, from the point of view of respondents, they believe that visualization is one of the benefits of BIM tools implementation among contractors at the construction phase. Besides, visualization offered many interesting features to the contractor that can help during the construction phase. Based on previous research, visualization tools include various visual simulations, such as digital images, animated videos, 360-degree panoramas, augmented reality solutions, and immersive virtual passage around the building in the very early stages of the creation of concepts. This is very beneficial during the project bidding stage, where the developer and construction manager can easily share the BIM idea with a variety of participating individuals (Veld, 2015).

5. Conclusion

In conclusion, this research was carried out in a successful way and achieved all the research objectives. The first objective of this research is to study the current practices of BIM tools among the contractor at the construction phase. The contractors are using BIM tools in their current practice during the construction phase. There are two current practices of BIM used by the contractor, which are Revit and Navisworks. The second objective of this research is to study the challenges of BIM tools among the contractors at the construction phase. Based on this research, the researchers found out the cost, training, ownership, resistance to change, and interoperability become the main obstacle to BIM implementation among the contractors at the construction phase. The third objective of this research is to study the benefits of BIM tools among the contractor at the construction phase. Regarding the data obtained from the respondents, visualization, reduction of design errors using clash detection, construction analysis and planning, integration with cost and schedule control, and other management functions and use for offsite fabrication are the benefits of BIM implementation among the contractors at the construction phase.

As we know BIM tools an expensive technology to be implementing. If there are few projects involving BIM technology, it would be a loss to the organization as it required a high cost and budget to implement it. Maintaining hardware and software subscriptions of BIM tools periodically requires a certain amount of expense, but they also need to be prepared for any situations when the devices are not working properly and renew software subscriptions. That is why the industry should find a solution to reduce the cost of implementing it such as applying for financial assistance from the Malaysian government because construction industries contribute high ROI for Malaysia every year. Finally, it is worth investing in BIM technology because of the features they offer.

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