POTENTIAL OF BUILDING INFORMATION MODELLING (BIM) IN IMPROVING SAFETY MANAGEMENT IN THE MALAYSIAN CONSTRUCTION INDUSTRY

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DEDICATION

For Allah the only God, for my beloved parents, family, and my friends.
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May Allah bless your kindness. Thank you.
ABSTRACT

The construction industry is one of the hazardous industries. The scenario makes the safety research in industry is very important. BIM is a 3-Dimensional (3D) object database that can be easily visualised, has rich data and structured information. To improve safety in the construction industry, BIM is used to detect and alert construction members to potential project hazard. This research discusses the improvement of safety management in the Malaysian construction industry through BIM implementation and to promote BIM implementation in safety management among construction player in Malaysia. Literature review was carried out to discover BIM implementation in safety management of the construction industry. Six (6) semi-structured interviews have been done toward the construction players such as client, contractor and BIM consultants that have experience in practicing BIM in construction projects in Malaysia. All data obtained from the semi-structured interviews were analysed using content analysis technique. The interview revealed that BIM have seven (7) advantage which are improvising 2D drafting, change management, convenience use of data, improve coordination, improve accuracy and efficiency, facilities management and enhance safety. However according to respondents, there are six (6) disadvantages in BIM implementation such as cost of BIM tools, cost of training, compatibility between software platforms, licensing issues, control of data entry and the adoption rate from 2D CAD to BIM. In safety aspect, there five (5) areas which BIM can help to improve which are excavation risk management plan, crane management plan, fall protection plan, emergency response plan, logistic planning of construction site, regular maintenance and forensic Investigation. The findings from the interviews provided clear evidence of the potential of improvement of safety management through BIM implementation. There are three (3) methods to increase the use of BIM for safety management in Malaysian construction industry such as government role, clear guidelines, standards and technical codes and education and Thus, the research could encourage BIM implementation in safety management in the Malaysian construction industry.
ABSTRAK

Industri pembinaan merupakan salah satu industri yang berbahaya. Senario ini menjadikan penyelidikan keselamatan dalam industri adalah sangat penting. BIM adalah 3-Dimensi (3D) objek yang mempunyai pangkalan data yang boleh dilihat dengan mudah, mempunyai data yang kaya dan maklumat yang berstruktur. Untuk meningkatkan keselamatan dalam industri ini, BIM digunakan untuk mengesan dan memberi amaran kepada ahli pembinaan jika terdapat potensi bahaya di tapak pembinaan projek Kajian ini membincangkan potensi BIM dalam meningkatkan pengurusan keselamatan dalam industri pembinaan Malaysia dan mencadangkan kaedah untuk menggalakkan penggunaan BIM dalam pembinaan pengurusan keselamatan di kalangan peserta di Malaysia. Tinjauan literatur dijalankan untuk mengenal pasti pelaksanaan BIM dalam pengurusan keselamatan. Enam (6) temu bual separa berstruktur telah dilakukan ke arah ahli pembinaan seperti pelanggan, kontraktor dan perunding BIM yang mempunyai pengalaman dalam mengamalkan projek BIM di dalam industri pembinaan di Malaysia. Semua data yang diperolehi daripada temu bual dianalisis dengan menggunakan teknik analisis kandungan. Hasil penemuan daripada temu bual memberikan bukti yang jelas tentang potensi peningkatan pengurusan keselamatan melalui pelaksanaan BIM itu. Temu bual telah mendedahkan bahawa BIM memberi kelebihan kepada projek pembinaan antaranya ialah memperbaiki draft 2D, pengurusan perubahan, kemudahan penggunaan data, meningkatkan penyelarasan, meningkatkan ketepatan dan kecekapan, pengurusan facilti dan meningkatkan keselamatan. Walau bagaimanapun menurut responden, terdapat enam (6) kelemahan dalam pelaksanaan BIM seperti kos peralatan BIM, kos latihan, keserasian antara platform perisian, isu-isu pelesenan, kawalan kemasukan data dan kadar penggunaan dari 2D CAD kepada BIM. Dalam aspek keselamatan, terdapat lima (5) perkara yang BIM boleh membantu untuk memperbaiki yang penggalian pelan pengurusan risiko, pelan pengurusan kren, pelan perlindungan terjatuh, pelan tindakan kecemasan, perancangan logistik tapak pembinaan, penyelenggaraan berkala dan siasatan forensik. Hasil penemuan daripada temu bual memberikan bukti yang jelas tentang potensi peningkatan pengurusan keselamatan melalui pelaksanaan BIM. Terdapat tiga (3) kaedah untuk meningkatkan penggunaan BIM untuk pengurusan keselamatan dalam industri pembinaan malaysia seperti
peranan kerajaan, garis panduan yang jelas, standard dan kod teknik dan pendidikan
dan Oleh itu, kajian ini boleh menggalakkan pelaksanaan BIM dalam pengurusan
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CHAPTER 1

INTRODUCTION TO RESEARCH

1.1 Introduction

Construction is one of the emerging industries in the world. It involves many activities from the interpretation of ideas into drawings and plans and to the contractor selection stage, and through the physical construction phase of the project when the project is completed and turned over to the owner. According to Anderson et al., (2006), the construction stages are divided into three main sections, simply described as pre-construction, construction and post construction. The complex and dynamic nature of the construction industry and its on-site work patterns is widely recognised. This separates it from the manufacturing industry, which are mostly stationary fabrication settings. Safety planning in an unstructured construction environment is thus more challenging (Zhang et al., 2013). Significant time and economic resources are lost when workers are injured on the jobsite. Some practitioners even claim that construction sites are often under-resourced and under-planned when it comes to safety planning (Charehzehi, and Ahandkoob, 2012).
Figure 1.1: Employees Accident by Sector for Death, Non Permanent Disability and Permanent Disability until June 2014 (Source: DOSH, 2014)

Figure 1.1 shows the statistic of occupational accidents by sectors in Malaysia from January 2014 until June 2014 from Department of Safety and Health (DOSH) Malaysia. Construction process gave effects in rising number of safety and health management problems. When safety issues arise, it will enhance the chance for a project to delay and lowering the project final product’s quality. In accordance with a statistic from DOSH (2014) from January until June 2014, the three (3) most dangerous industries that lead to occupational accidents are manufacturing, agriculture, and construction. The manufacturing industry in Malaysia lead the other industries in aspect of occupational accidents with a total cases of 964 cases including 24 cases of death, 866 cases of non-permanent disability and 74 cases of permanent disability. The second most dangerous industry in Malaysia is agriculture, forestry, logging and fishing. There are total of 224 cases including 22 death cases, 198 non-permanent disability cases and 4 permanent disability cases. Meanwhile, construction industry is in the third place with a total of 85 cases including 35 cases
of death, 48 cases of non-permanent disability and two (2) cases of permanent disability. According to DOSH (2014), most fatal accidents occur due to falling from height and struck by falling objects. Furthermore, from the observation by DOSH, the factors that contributed to the accidents are because of no safe work procedure working at height and no appropriate supervision by the site management team. According to Puerto & Clevenger (2011), such accidents highlight the fact that personal protective equipment is, generally, an imperfect and last resort to protect workers from work and health hazards, since its effectiveness depends on its adequate use by the employee. In addition, Puerto & Clevenger (2011) also states that the need for personal protective equipment can be reduce through better design solutions provides a higher level of protection to all workers by providing protection independent of worker action.

Recently, technology advancement gives birth of a new era in the construction industry worldwide. With the advancement of Information Communication and Technology (ICT) nowadays, all construction information is digitised; the architectural plans, structural plans are drawn using computer (Azhar, Hein & Sketo, 2011). The positive explosion of ICT usage in the industry is widely spread. One of the ICT that can be apply to the construction industry is through Building Information Modelling (BIM). BIM provides a powerful new platform for developing and implementing “design-for-safety” tools and methods to facilitate both engineering and administrative controls during design and construction (Puerto & Clevenger, 2011).

Definitions of BIM are differ throughout the world. For instance Azhar, Hein and Sketo (2011) state that BIM represents the process of development and use of a computer generated model to simulate the planning, design, construction and operation of a facility, from which views and data appropriate to various users needs can be used to improve the process of delivering the facility.

Currently, BIM has been implemented in many countries such as the United Kingdom (UK), Australia, Hong Kong, Denmark, Norway, Finland and Singapore (Furneaux and Kivit, 2008; Mohd and Latiffi, 2013). In 2010, 36% of the Western European industry participants were adopting BIM. This can be compared to the 49% adoption rate in North America (McGraw-Hill Construction, 2010). In Malaysia, the idea to implement BIM was introduced in 2007 by the Director of Public Works Department (Mohd and Latiffi, 2013).
In Malaysia, BIM mainly utilize to reduce construction cost and avoid design problems in planning phase. BIM was brought in the industry as the sign of government’s awareness of the potential of BIM. Moreover, BIM also has been seen as a concerted action to ensure collaboration between construction players such as architects, engineers, project managers and contractors (JKR, 2013). However BIM is not widely used in Malaysia due to lacking support received from the management as they did not realize the benefits and the importance of BIM in construction projects, CIDB (2011). The implementation of BIM in Malaysia is often involves more on the process design. Malaysian government encourages construction players to apply BIM to construction projects because it can overcome construction project problems such as delay, clash of design by different professionals and construction cost overrun (Ahmad Latiffi et al., 2013).

Nowadays, there has been considerable interest in improving worksite safety through safer design and work method statements using BIM (Chi et al., 2012). A building information model allows constructors to visually assess jobsite conditions and recognize hazards (Azhar et al., 2012). Thus, with the progress in the field of information technology (IT), BIM can be applied to construction activities to reduce the problem faced in the industry. Current researches and industry practice provide example of successful use of BIM for clash detention and circulation analysis. It allows virtual safety controls which can be used to detect and alert designer and contractors to potential project hazards (Puerto & Clevenger, 2012).

With the approach on BIM, it allows features such as information sharing within an interface by many parties. In addition by Sulankivi et al., (2012) the utilisation of BIM technologies can result in improved occupational safety by connecting the safety issues more closely to construction planning, providing more illustrative site layout and safety plans, providing methods for managing and visualising up-to-date plans and site status information, as well as by supporting safety communication in various situations, such as informing site staff about making safety arrangements in response to a particular risk or warning about various risks. The use of BIM also encourages other project partners to involve in both risk assessment and planning (Sulankivi et al., 2012).

Therefore, a research on the potential of BIM in safety management aspect in the Malaysian construction Industry is needed to help the industry in finding an alternative of safety practices applicable in industry.
1.2 Research Background

Nowadays, construction industry is one of the biggest industries expanding in the world parallel to the improvement of technology. The construction industry undoubtedly plays a significant role in the development process of a country, contributing towards employment and economic growth. However, construction industry has proven to be a highly hazardous industry due to its fatality rates despite recognition on good safety cultures (Abdullah & Wern, 2011). Besides the rapid activities in the industry, there is a lot of problems arises including accidents in which the construction site lead to injuries and even fatal (Hanapi et al., 2013).

According to (Charehzehi and Ahandkoob, 2012) those who spend their working lives on construction sites have a higher probability which is about 1 in 300 chance of being killed at work. (Charehzehi and Ahandkoob, 2012) stated that over the years the construction industry has had among the highest reported rates of work-related deaths and injuries.

The high accident frequency is still globally a real safety challenge in the building construction sector. When compared with other industries the construction jobs are infamous for being the most dangerous occupation. According to the USA based Occupational Health Administration (OSHA) 31 per cent of all workplace fatalities occur in the construction industry. This frequency in figures meant 9,5 fatalities per 10,000 construction workers in Europe in 2006 and 11 fatalities per 100,000 workers in USA in 2007 (Kiviniemi et al., 2011).

In year 2014, Department of Safety And Health of Malaysia recorded a total of 85 cases including 35 cases of death, 48 cases of non-permanent disability and 2 cases of permanent disability until June 2014 (DOSH, 2014).

Designers have held responsible in conventional safety practices for safety of end –users and considered constructors responsible for safety of construction workers. Taiebat (2011) states that, the construction industry is on the top list of hazardous industries which justified the importance of safety research in industry. According to Puerto & Clevenger (2012), accidents in workplace can be avoided by improving engineering, administrations controls, and improve safety training. One of the important aspects in safety planning is to properly understand hazard before they occur. Construction players such as project managers, safety officer,
safety engineer and architect are allowed to assess jobsite conditions visually while recognising hazards through a BIM application, this will give them enough time to develop hazard precaution plans.

BIM also called n-D Modelling or Virtual Prototyping Technology is a revolutionary development that is quickly reshaping the Architecture-Engineering-Construction (AEC) industry (Azhar et al., 2012). In addition, Azhar et al., (2012) states that the technology component of BIM helps project stakeholders to visualise what is to be built in a simulated environment to identify any potential design, construction or operational issues. Referring to Behringer and Azhar (2012), occupational safety will be improved by connecting safety issues more intimate to construction planning by the use of BIM.

1.3 Problem Statement

In the future, the construction industry would be challenged by increasingly difficult and complex problems in both engineering and management. According to Hsiao et al., (2006), construction industry is a high risk industry because there is a high risk of accident occurrence.

Construction stages involve many risks. The safety measures in a project especially in Malaysia are arguable. Safety received a great concern of participants but environment of industry is proven as an unsafe place to work. The extensive references of fatality studies in construction showed that high rates of fatalities are reported for the construction industry.

In Malaysia, there are many safety standards that should be follow by the construction players in order to ensure the safe environments during the construction project stages and also at the construction site. Department of Safety and Health (DOSH) Malaysia (2014) has prepared several guidelines, acts, regulations, order and codes of practices for the Malaysian construction industry such as factories and machinery act (amendment) (2006), occupational safety and health act 1994 (act 514), regulations under occupational safety and health act 1994 (act 514) and guidelines under building construction and engineering work.
The main objectives of the guidelines, acts, regulations order and codes are practices are to ensure there are sufficient safety precautions are taken during the construction works to avoid any accidents and harm due to the hazardous activity of construction project (DOSH, 2014). Preparation of safety equipments such as safety boots, safety helmets and scaffolding for work in high places are examples that was subjected in the guidelines, acts, regulations order and codes are practices required by DOSH.

An independent method to assess and evaluate the safety and health performance of a contractor in construction projects were design. This method is called Safety And Health Assessment System in Construction (SHASSIC). According to Ramuseren (2009), SHASSIC is intended to complement the normal contractual requirement and specification in a project.

It is not intended to be used independently as working requirement and specification. Unless specified in the project contract, safety and health designated person should not use SHASSIC to decide if the project site or parts of the project site are in accordance with requirement of the relevant Acts and Regulations or OSH Management System (Ramuseren, 2009). It is still the responsibility of the contractor to ensure that safety and health of construction site conforms to legislations requirement, approved standards, code of practice, guidelines, specifications and contractual requirements (Ramuseren, 2009). Despite the measures taken by the government bodies such as DOSH and CIDB, accidents in construction sites is still in worrisome and alternatives prevention method of the potential hazards should be identify

According to Puerto & Clevenger (2011), 3D visualisation and analyses is one of the important aspects that play a critical part in improving safety. For example BIM enabled safety controls can be used to detect and alert designers and contractors to potential project hazard. By using BIM in safety management, the project can increase the quality of projects. BIM is useful in assisting construction players to construct small or high—risk projects successfully (Furneaux & Kivit, 2008).

BIM can enhance construction site safety (Puerto and Clavenger, 2011). According to Azhar et al., (2011), architects, contractors and engineers were helped by BIM to visualise what is to be built in simulated environment while recognising potential design, construction or operational problems.
In Malaysia, BIM was only initiated late in 2007 based on report by PWD (2007). According to Ahmad Latiffi et al., (2013) BIM in Malaysia is often involves more on design. Malaysian government gives encouragement to the construction players to implement BIM because it can overcome construction problems such as delay, clash of design and construction cost overrun (Ahmad Latiffi et al., 2013). Lack of literature findings on implementation of BIM in safety management aspect in Malaysian construction industry indicates that there are lack of awareness and knowledge of construction players in Malaysia about the potential of BIM in safety management aspects.

Therefore, this research is made in order to study on potential of BIM towards safety management aspects in the Malaysian construction industry and to suggest the ways to promote BIM usage in reducing safety issues among construction players in Malaysia.

1.4 Research Questions

To study on the potential of BIM in reducing safety and health management issues in Malaysian construction industry, two questions were presented in this research. Thus, the research questions are as follows:

1) How BIM can improve safety management in the Malaysian construction industry?
2) What are the ways to promote BIM implementation in safety management among construction players in Malaysia?
1.5 Research Objectives

This research is to study on the potential of BIM in reducing safety and health management issues in Malaysian construction industry. Thus, the research objectives are as follows:

1) To identify the improvement of safety management in the Malaysian construction industry through BIM implementation.
2) To promote BIM implementation in safety management among construction players in Malaysia.

1.6 Research Scope

This research focuses on construction players whom have practiced BIM and are practicing BIM in construction projects in Malaysia. Specifically, the construction players that have involved in this research are clients, contractors and BIM consultants. Client was chosen because they are the owner of the project, and they have the information regarding the project and safety practices in the project. Contractor was chosen because they understand the most about implementation of safety measure in the construction site. Contractors also were chosen because they have their own safety officer and safety engineer in every construction site which is required by Department of Safety and Health Malaysia. Therefore contractor will realise more about how safety and health management was applied in Malaysian construction industry. BIM consultants were chosen as they were well trained and knowledgeable about BIM design and BIM usage. They have the ability to detect the benefits and the problems by implementing BIM moreover in aspect of safety and health management.
1.7 Significance of Research

In the pre-construction stage, the construction players of the can gain benefit by this research in aspect of planning the design base on 4D models with respect to the safety. From this research, they will realise the importance of having a good safety management planning by 4D modelling to avoid unwanted incidents in the construction phase.

This research is expected to help contractors to determine the safety issues arose in the construction industry. Contractors have to play it roles in controlling or minimising the hazards by using BIM. Labours, site supervisor and engineers at the site also gain benefit from this research as their life at the workplace is safer due to the application of BIM. The labours were informed by the management at the site if there are any particular hazards on their activities during that time. Therefore, the labours work in a safe and confident environment and it increase their production level.

In post construction stage, the management level are be able to reduce the safety issues compared to the project that do not utilise BIM their project. By reducing the safety issues, top management also can reduce the money that allocated for the medical bills and compensation to the construction players if any safety problems arise. The increment in productivity lead to a time efficient and it also benefit to client. Client always ask for a project to finish on schedule or earlier than that. Therefore, client gain a lot of benefit from this research in aspect of cost and time. This research also explains the steps to encourage the applications of BIM among construction players in Malaysia. Through this research, construction players can use it as a stepping stone to take the first steps towards applying BIM in their projects.
1.8 Research Methodology

Research methodology is an approach to review and to control research process (Fellows and Liu, 2009). Figure 1.2 shows research methodology process for this research in order to achieve the research’s aim and objectives.

Figure 1.2: Flow Chart Of Research Methodology

Based on figure 1.2, during the planning phase, the researcher has read the background of construction industry and safety management aspect in construction industry. After that, the researcher came with several title that is suitable to achieve the objective of Master Project. From the several title, the researcher then made a selection of topic based on safety management in construction industry. The research
which is on the potential of BIM in safety management aspect in Malaysian construction industry was selected. The researcher has produced an initial draft and found the definition of the research.

Next, in the literature review process, the researcher found the facts and accurate secondary data related to the potential of BIM in safety management aspect in Malaysian construction industry that was selected through books, journals, reports, thesis, magazines and the internet. The aim is to provide in-depth knowledge of the research which were conducted in order for the research to run smoothly.

After that, the method based on the scope of the research was determined. The research methodology determined must meet the objectives of the research that has been fixed from the start of the research. In the data collection stage, primary data were obtained through the semi-structured interview with the construction players which were using qualitative survey method. The first advantage is a researcher may face respondents and this allows both sides to explore the meaning of the question and responses involved (Patton, 2002). Any misunderstandings between researchers and respondents can be checked and corrected immediately and this affect the credibility of studies (Othman, 2006). Other advantages of interview method is when excess input from respondents and if they are mistaken, or did not understand the question, the data obtain from respondents can be separated (Patton, 2002). After the data were obtained, the analysis stage take place.

The data were analysed using content analysis. The result of the analysis were reported and the recommendation were presented for the benefits of the future research.

Next, conclusion was made based on the analysis of the research objectives. Besides, recomendations were made for future research and also in order to promote a greater BIM implementation in improving safety management in Malaysian construction industry.
1.9 Summary

This research was made to study the potential of BIM in safety management in Malaysian construction industry. This research also developed ways to promote BIM usage in reducing the safety issues among construction players in Malaysia. The safety and health management are one of the concerns in the Malaysian construction industry. Based on previous study, BIM can help in safety and health management however in Malaysia, the implementation of BIM is more focus on design to reduce construction cost and avoid design problems in planning phase. This research focused on client, contractor and BIM consultant as well as high-rise building. Usage of BIM in a project will help the project to reduce its safety issues and therefore can increase the productivity in the sector. As the Malaysian construction industry are lacking the relevant data about the potential of BIM in safety management aspect, this research can contribute towards achieving an even better practice in the Malaysian construction industry.

Next chapter focused on literature review related to BIM in safety management in the Malaysian construction industry.
CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter contains discussion on BIM in the safety management aspects in construction industry. This chapter aim is to explore on potential of BIM in improving safety management in Malaysian construction industry.

2.2 Definition of BIM

The BIM definition depending on how the past researcher has used the BIM. Some of the researchers may have implemented BIM in the field to increase the integration of communication. Therefore, BIM is viewed by the researcher from the perception on the field of communication. Some researcher may implemented BIM to increase safety and other aspects such as scheduling, visualising and modelling. For better understanding of BIM, the basic definition of understanding of BIM should be understood. Table 2.1 show the definition of BIM.
<table>
<thead>
<tr>
<th>No</th>
<th>Year</th>
<th>Author</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2008</td>
<td>Sabol</td>
<td>A complete 3D digital representation of a building system or subsystem, which is both a visually accurate model of a building and a database for recording the breadth of information developed and associated with building components.</td>
</tr>
<tr>
<td>2</td>
<td>2009</td>
<td>Words And Images</td>
<td>Use of a 3D building model to analyse the designed building’s energy efficiency by running “what if” scenarios to determine the best of several potential solutions. The software can automatically take off all items contained in the model and that way produce an impressively precise estimate.</td>
</tr>
<tr>
<td>3</td>
<td>2009</td>
<td>Thomsen</td>
<td>A technology for collaboration, an integration tool for the fragmented and specialised building industry which allows building to be build virtually, before building physically, uncovering problems of sequence, interference and constructability of the building</td>
</tr>
<tr>
<td>4</td>
<td>2011</td>
<td>NBS BIM</td>
<td>Rich information model consisting of potentially multiple data sources, elements of which can be shared across all stakeholders and be maintained across the life of a building from early inception to post-construction stages.</td>
</tr>
<tr>
<td>5</td>
<td>2011</td>
<td>NBS BIM</td>
<td>The process of creating and using electronic data models of buildings to facilitate a co-ordinated understanding of a broad range of real world building issues, both as a design or specification tool and as an analytical tool for achieving statutory approvals or client driven performance requirements.</td>
</tr>
<tr>
<td>6</td>
<td>2011</td>
<td>Shourangiz et al.</td>
<td>An IT enabled approach that involves applying and maintaining an integral digital representation of all building information for different phases of the project life cycle in the form of a data repository.</td>
</tr>
<tr>
<td>7</td>
<td>2011</td>
<td>Rajendran And Clarke</td>
<td>The development and use of a computer software model to simulate the construction and operation of a facility</td>
</tr>
<tr>
<td>8</td>
<td>2012</td>
<td>Azhar et al.</td>
<td>A virtual process that encompasses all aspects, disciplines, and systems of a facility within a single, virtual model, allowing all team members (owners, architects, engineers, contractors, subcontractors and suppliers) to collaborate more accurately and efficiently than traditional processes.</td>
</tr>
<tr>
<td>9</td>
<td>2012</td>
<td>Arayici, Egbu &amp; Coates</td>
<td>The utilisation of a database infrastructure to encapsulate built facilities with specific viewpoints of stakeholders</td>
</tr>
</tbody>
</table>

### Table 2.1 : Definitions of BIM
Table 2.1: Definitions of BIM throughout the world (continued)

<table>
<thead>
<tr>
<th>No.</th>
<th>Year</th>
<th>Source</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>2012</td>
<td>Building Smart Australasia</td>
<td>A 3D object database that can be easily visualised, has rich data and structured information. BIM is a process of representing building and infrastructure over its whole life cycle from planning, design, construction, operations, maintenance and recycling.</td>
</tr>
<tr>
<td>11</td>
<td>2012</td>
<td>HM Government</td>
<td>A collaborative way of working, underpinned by the digital technologies, which unlock more efficient methods of designing, creating and maintaining the assets. It embeds key products and asset data and a 3D computer model that can be used for effective management of information throughout a project lifecycle - from earliest concept through to operation.</td>
</tr>
</tbody>
</table>

For this research, the definition of BIM were referred in context of manipulating BIM to analyse “what if” scenarios to determine the best of several potential solutions especially in aspects of safety purpose in the construction industry as mentioned in the definition of BIM by The Foundation of Wall And Ceiling Industry. Therefore, the definition of BIM is not rigid to one particular means but it differs through the globe.

2.3 BIM Tools

Building Information Modelling (BIM) is not particular software, it is a system of process. Communication reliability can be seen through BIM process in defining a project team, identifying the key processes and dependencies throughout a project, assigning roles and assigning responsibilities to each project team (MSC, 2013).

BIM tools have been introduced in many types and functions. Among the tools are Revit, Tekla, Bentley, Autodesk, Vico and Cost X. Each tool has its own functions, and they are each used to manage different activities in construction projects (Cream, 2012). The selection of BIM tools is based on four (4) features, which are communication reliability, accuracy, usability and reliability of data exchange (JKR, 2013).
The application of BIM in estimating process shows the accuracy of BIM during the taking-off process. BIM can reduce the number of errors related to measurement estimates during the estimating process (Nassar, 2012). Through this process different construction players make useful and sufficient communication and collaboration by distributing design data to all the construction players involve in order to increase productivity and reduce errors. Therefore, BIM is a combination of different software group known as BIM tools.

Figure 2.1 : BIM tools Suggested by Malaysian Public Work Department. (*Latiffi et al.*, 2013)

2.3.1 **Autodesk Revit Architecture**

Autodesk is a leading BIM software vendor in Architecture, Engineering & Construction (AEC) industry. They was founded in 1982. Autodesk focuses on 2D and 3D design and animation software for media also. Autodesk makes a pioneer
movement in BIM from 3D CAD to intelligent design systems. Autodesk provides design software which is also used widely in manufacturing industry. Malaysia Public Work Department (PWD) acknowledged that BIM tools from Autodesk applicable to the industry which serves as the tools for BIM platform for Malaysian government. This has been officially declared by the PWD on 25 February 2010 (JKR, 2013; Latiffi et al., 2013). Autodesk Revit Architecture possess the BIM functionality and widely used in architecture and design community due to better collaborative and integrated building design system. It retain all the BIM functionality that makes it better in design with maintaining documentation and construction. It has data interoperability with other BIM solutions and has unique features on sustainable design analysis, clash detection, construction planning, and material fabrication (Autodesk, 2014).

Architect can utilise Revit Architectural to illustrate construction processes through 4-Dimensional (4D) simulation and clash detection (Autodesk, 2014).

2.3.2 Autodesk Revit Structure

Autodesk Revit Structure provides structural BIM model contains information for structural design and analysis. Also provides structural design drawings with real visualisation and makes a bridge on data share between architect and structural design team. Fabrication has the another important feature of this solution also (Autodesk, 2014).

In addition, an architect uses Revit Architecture to design plans of every aspect of a building including walls, staircases, doors and roof. Revit Structural allows structural engineers to perform structural design and analysis by modelling building using the basic components of walls and a foundation (Autodesk, 2012). Revit Structural are able to illustrate construction processes through 4-Dimensional (4D) simulation and clash detection (Autodesk, 2014).
2.3.3 Autodesk Revit MEP

Autodesk Revit MEP is a Building Information Modelling solutions for mechanical, electrical and plumbing designers. Revit MEP has interoperability with other BIM design software like with Revit Architecture for collect the architectural model data and other revit software such as Revit Structural. Revit MEP is used for MEP system design and analysis which permits better coordination with sustainable and cost effective MEP design. (Autodesk, 2013)

Revit MEP can be used by mechanical engineers to develop a model of ducts, piping and to gain a better understanding of HVAC zones (Autodesk, 2012). On top of that, Revit MEP allows electrical engineers to model placement of light fixtures as well as to create circuits and wiring. All of these tools can be used to create drawings in 2 Dimension (2D) and 3D (Autodesk, 2013).

2.3.4 Autodesk Navisworks

Autodesk Navisworks software is used for advanced analysis process like clash detection and project simulation. Also used for combining and reviewing the design data which are created through different BIM software. (Autodesk, 2013)

Moreover, project managers can use Autodesk Navisworks to create a multidiscipline model to simulate and optimize scheduling, identify and coordinate clashes as well as establish collaboration between contractors and design team, which consists of architects, structural engineers as well as mechanical, electrical and plumbing (MEP) engineers; this collaboration enables the team to gain insight into potential problems (Autodesk, 2013).
2.3.5 Exactal Cost-X Construction Estimating

From a cost efficiency point of view, central to any BIM strategy is an emphasis on value for money, standards, cost benchmarking and sustainability. Whilst there is nothing new in these requirements, the way and speed they can be achieved can be improved significantly by the use of CostX as part of a BIM workflow. As an interoperable estimating software tool, CostX allows the seamless transfer of digital information between Designers, Cost Managers and Estimators (Exactal, 2014). This allows fast and extremely simple extraction of cost geometry and building dimensions from CAD files and BIM models to provide faster, more accurate take-offs for measurement, estimating, analysis and options resolution.

CostX is renowned worldwide as a leading BIM estimating solution and is used in a variety of industries for this reason. Construction players can view and takeoff from 3D models / BIM within the program which can support 5D BIM using information from the model live-linked to user-defined rate libraries and workbooks— all within the one program (Exactal, 2014). Furthermore according to exactal (2014), networked environment allows instantaneous information sharing with others working on the server. CostX also imports a multitude of drawing files and external rate information, and exports to a variety of formats, taking interoperability to a new level. It’s never been easier to bring BIM into your business with CostX.

According to Latiffi et al., (2013), the PWD acknowledged that BIM tools from Autodesk and Exactal Cost-X were applicable to the industry. The tools serve as an application platform for Malaysian government (Latiffi et al., 2013).

2.4 Advantages of BIM Application In Construction Projects

BIM can be implemented in the construction phases. There are many benefits of using BIM. Some of the advantages are:
2.4.1 Improving 2-Dimensional (2D) drafting

BIM improves over 2D drafting by allowing the designers to view the building and its content from 360 degrees (360°). BIM is more than 3 dimensional drawing; it is a data repository that holds design, construction and maintenance information combined in one convenient model that can be shared with all the stakeholders (Mitchell and Keaveney, 2013). BIM can verify and show potential problems during the earlier stage of construction such as clash detection (Mitchell and Keaveney, 2013). Construction players will be able to do corrections at the earlier stage and thus will reduce cost of the rework (McNell et al., 2011). BIM allows process of producing and editing multiple design portions in the same time which is proven to save time (Shourangiz, 2011).

The use of BIM significantly reduces the time required to generate shop drawings and material take offs for procurement (Shourangiz, 2011). An alteration to any one of these elements will give effects to the others such as cost, scheduling of the projects and material (McNell et al., 2011).

2.4.2 Change Management

Construction industry is a very gullible to changes. Changes happen in different phases in construction such as in the pre-planning stage (Shourangiez et al., 2011). Design change is defined as the changes resulting from a modification within or outside the original scope of work and require re-design and revision to the contract documents (Shourangiz et al., 2011).

According to Mitchell and Keaveney (2013), all corresponding views and locations change if one parametric element in one location is changed. BIM process promises consistency in documentation thus allowing greater project visualisation (Mitchell and Keaveney, 2013). BIM also will provide early warnings and flags to enhance the visibility among managers to see the changes in any views. These warnings will be arranged into an elements change report to facilitate coordination (McNell et al., 2011).
2.4.3 Convenience Use of Data

BIM makes the data of a project to be used conveniently. According to Shourangiz et al., (2011), BIM is a comprehensive concept of process and tools which integrates all required data and information for specific projects. From new management paradigm, the integration can be implemented through varies of building software such as Primavera, Revit, and Naviswork Managerial processes and concepts such as critical chain project management, critical path method and concurrent engineering at all projects life cycle can be utilised.

BIM is a tool which possess a rich database that contains information about manufacturers, pricing, physical information (such as material weight and size) and also electromechanical devices in the building. The integration of BIM application allows the architect to has a BIM model, which has integrated to the model of the mechanical, electrical and plumbing (MEP) of the building (Sullivan, 2007). Convenience use of data means very precise schedule of materials can be developed from the parametric model elements and the parametric model elements will automatically change with visual components. Accurate materials schedules allow team members to project usage of the material before construction complete (Mitchell and Keaveney, 2013).

2.4.4 Improving Coordination of Project Team Members

BIM is laid on two pillars, communication and collaboration. BIM enables all team members to easily access the information about each building component within its modelled elements (McNell et al., 2011). The information such as power consumption and weight of an element can be accessed by the team (Azhar et al., 2012)
Figure 2.2: A comparison between traditional and BIM process (McNell, 2011)

Figure 2.2 shows comparison between traditional process and BIM process. In traditional process, there is a separated process between concept design, documents and drawings and construction and operation. In BIM process, all process related to the construction and operation of a building are integrated and used throughout the construction stages such as cost estimation, documentation and drawings and facilities management (McNell et al., 2011). The information is used and integrated through active access and sharing of data among the construction players and this improve coordination among construction players (Mitchell and Keaveney, 2013).

2.4.5 Improving Accuracy and Efficiency of Project Team Performance

In conventional construction processes without BIM utilisation, Building project teams rarely work together more than once. Each of these parties has resorted to concentrating on contractual arrangements to prevent liability and this has formed impediments to collaboration and innovation in the design and construction phases (Mitchell and Keyveney, 2013). The team performance is often influenced by the accuracy and efficiency of the team. Most processed in BIM are automated and the involvement of human resources is minimised, it is claimed that by using BIM, the
efficiency of monitoring, controlling and updating in construction projects life cycle enhanced remarkably (Shourangiz et al., 2011).

The integration of one element to another in BIM increased accuracy for quantity takeoff. Integrators scheduling based on material availability and progress can be shown visually. By a visual presentation, project managers can quickly optimise construction schedules with ever-changing materials deliveries, cost and availability (McNell et al., 2011). In addition Mitchell and Keyveney (2013) states that BIM process promises consistency in documentation, promotes collaboration among construction players and offers many application that can be used to improve efficiency.

2.4.6 Facilities Management (FM)

The facility management is made easier by BIM usage. The rationale for using BIM goes beyond the ease of use of the BIM models. Other reasons include productivity gains, project controls, rapid visualisation capabilities, and downstream uses of the database built into the model, such as for facility management and operations (Sullivan, 2009).

According to Mcnell et al., (2011) facilitates managers can use BIM to gather usage data, prepare maintenance schedules using predictive data, manage daily operations and plan for future purchases and construction additions. Full equipment data including operating parameters, usage data, predictive data, service history, replacement price and links to other manufacturer data, combined with a fully rendered 3D depiction of the equipment creates a powerful tool for facility managers ( Shourangiz et al., 2011)

2.4.7 Enhance Safety in Construction Project

Project team is leveraging BIM and collaborating design review to enhance and improve the health, safety and welfare (HSW) performance of their projects. Such HSW advantages include enhanced occupant safety. BIM is identified as a possible tool which may help to improve safety management by allowing job-hazard analysis
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