BUILDING INFORMATION MODELLING IN INTEGRATED PRACTICE

Ahmad Tarmizi Haron[1,2], Amanda Jane Marshall-Ponting[1], Ghassan Aouad[1]

ABSTRACT

Integrated practice in construction industry is identified as one of the solution that could be used to minimise the problems associated with fragmentation in construction. Many solutions are identified to support integrated practice and such of them are Integrated Project Delivery, Integrated Design Solution and nD Modelling. The aforementioned solutions, however, have the similarity where they are all using Building Information Modelling as a part of the process. Through a literature review, this paper is highlighted the definition and concept of Building Information Modelling. Several benefits of implementing Building Information Modelling is also discussed which covers the visualization and collaboration benefit, synchronization of design and construction planning, conflict detection and cost reduction. This paper concluded the Building Information Modelling could provide an ideal platform for integrated practice since it is capable of integrating and linking the project information to the data level.

Keywords : Integrated Practice, Building Information Modelling, Integrated Project Delivery, Integrated Design Solution and nD Modelling

1.0 INTRODUCTION

The construction industry could probably be known as one of the most challenging industries in many countries. Even though its existence is longer than other industries like automotive and manufacturing, still there are a lot of issues that need to be focused on. A Low and reliable rate of profitability, little investment in research and development, crisis in training to replace aging people and client tendency of selecting the lowest price are among of the issues raised by the Construction Task Force Report (1998). While on the other hand, improper planning, lack of control, subcontractor delays and improper construction methods have worsened the condition of the industry (Hensey, 1993). However, some believe that fragmentation within the industry itself has inhibited performance improvement (Construction Task Report, 1998; Bouchlaghem et al., 2004 and Aouad et al., 2003). While, according to AIA Guide (2007) on the other hand, many studies document inefficiencies and waste in the construction industry. For example, an *Economist* article from 2000 identifies 30% waste in the US construction industry; an NIST study from 2004 targets lack of AEC software interoperability as costing the industry $15.8B annually; and a US Bureau of Labor Statistics study shows construction alone, out of all non-farm industries, as decreasing in productivity since 1964, while all other non-farm industries have increased productivity by over 200% during the same period.

Much evidence has pointed out that, the fragmentation in construction is the root cause of many problems occurring in a construction project. According to Anumba and Evbuomwan (1997), the fragmentation in construction has created inter alia: an adversarial culture, information with data generated at one stage that could not be automatically available for re-use downstream and lack of real life cycle analysis. Also, it creates difficulties in changing and

1.University of Salford, 2. University Malaysia Pahang

adapting design, planning and cost estimate (McKinney And Fischer, 1998; and Aouad et al., 2003), over the brick effect (Aouad et al., 2007) and unable to link impact of design on construction decision (McKinney and Fischer,1998). While on the other hand, it has also caused poor coordination as mentioned in research by Rad (1979), Hensy (1993), Lee and Sexton (2007) and Bilal (2008), difficulties in promoting collaborative environment (Heesom and Mahdjoubi, 2004; and Marshall-Ponting, 2006) and ineffective communication (Marshall-Ponting, 2006; Lee and Sexton, 2007; David and Mahdjoubi, 2004 and Hensy, 1993). To make it worst, Marshall-Ponting A.J (2006) also identified that fragmentation would allow information wastage , lots of repetition and long lead time, together with redundant and replicated work at different interfaces between department and slow product development and process improvement.

The problems associated with fragmentation in construction industry also been worsened by the current practice of information sharing and communication. According to Eastman et al. (2008) the delivery process depends on paper based of communication. Errors and omissions in paper documents often cause unanticipated filed costs, delays and eventual lawsuits between various parties in a project team. They further indentified, that one of the most common problems associated with paper-based communication during design phase is the considerable time and expense required to generate critical assessment information about a proposed design, including cost estimates, energy-use analysis, structural details, etc. These analysis are normally done last, when it is already too late to make important changes.

Therefore, there is a need to develop integrated product and process information that offers the potential for improved collaborative working as agreed by Anumba et al. (1998). While, McKinney And Fischer (1998), focus more on IT tools to support collaborative working by identifying the need to incorporate 4D principles with other construction/Built Environment Software tools like GIS, Cost Estimation and Safety and health. Meanwhile, in the AIA (2007) guideline, they also agreed that new technologies have emerged, that when utilised in conjunction with collaborative processes, are demonstrating substantial increases in productivity and decreases in requests for information, field conflicts, waste, and project schedules. They suggested that Integrated Project Delivery with the utilisation of Building Information Modelling could improve the construction process. Back on a couple of decades ago and still ongoing, much research been conducted all over the world to facilitate or even to solve the problem of fragmentation in construction. The focus of the research not just limited to the tools or technology to support integrated practice in construction industry but also concentrates on people, process and technology to support it.

Many researchers and construction industry practitioners dealing with fragmentation of construction would agree that integrated practice could solve many problems within construction. And therefore, many efforts have been driven to explore in depth on how it could really applied and any other potential that it could bring to the industry. Consequently, many approaches and concepts has been identified, developed, introduced and tested to support integrated practice in construction. Such of them are, to name a few are Concurrent Engineering (Anumba et al, 1998; Love and Gunasekaran,1997) , web based project management (Anumba et al, 2008; Alshawi and Ingirige, 2003), Partnering (Bresnen and marshall, 2000; Barlow et. al (1997) , Building Information Modelling (Eastman et al., 2008; Sacks et. al., 2005; Howard and Bjork, 2007), 4D modelling (Fischer, 2001;Heesom and Mahdjoubi;2004), *n*D modelling (Aouad et al., 2007;Lee et al. 2003) and Integrated Project Delivery (AIA, 2007)

2.0 THE USE OF BIM TO SUPPORT INTEGRATED PRACTICE

Among the solutions, many would believe that the use of BIM as the repository could efficiently achieve the collaboration required for integrated practice. One of them is Integrated Project Delivery (IPD) which has been introduced by the American Institute of Architect (AIA) where in the IPD guide it is stated that, IPD and Building Information Modelling are different concepts where IPD is a process and Building Information Modelling is a tool. The full potential benefits of both are achieved only when they are used together. Furthermore, in the discussion of delivering an Integrated Project in the guide, the assumption made is when the project used Building Information Modelling as a tool. It is clearly described that the application of Building Information Modelling is important in IPD. For the definition, IPD is a project delivery approach that integrates people, systems, business structures and practices into a process that collaboratively harnesses the talents and insights of all participants to optimize project results, increase value to the owner, reduce waste, and maximize efficiency through all phases of design, fabrication, and construction. The approach is built upon early contribution of individual expertise which requires early involvement of all project participants as early as during design phase.

On the other hand, CIB also supporting integrated practice in construction industry by launching Integrated Design Solution as a priority theme of CIB. The theme "Improving Construction and Use through Integrated Design Solutions" (IDS) has been under development since early 2006 and in June 2009, CIB IDS 2009 First International Conference was held. The theme aims at speeding up the adaptation of techniques and practices that guide the traditional document-based work methods towards the use of Integrated Building Information Modelling. In CIB context, IDS is defined as an improved collaboration, communication and decision support enabled by horizontal and vertical integration of data and information management in the whole value network throughout the building lifecycle.

The use of BIM has also been extended by the work that been carried out by The University of Salford, From 3D to *n*D modelling project which aimed to integrate an *n*th number of design dimensions into holistic model which would enable users to portray and visually project the building design over its complete lifecycle. In the project, the model developed is based upon the Building Information Model where the BIM will be a repository that stores all the data objects with each object being described only once. In the project, the dimension that been incorporated into the model are whole-lifecycle costing, acoustic, environmental impact data, crime analysis and accessibility. The uniqueness of the work carried out by the university however, is that it could enable the what-if analysis to be carried out before the real construction takes place; for instance what are the knock-on effects for time, cost, maintainability, etc of widening a door to allow for wheelchair access.(Marshall-Ponting and Aouad, 2005).

Comparing the efforts which have been carried out by AIA, UoS and CIB, to name a few, they are all sharing a common goal which is to realise integrated practice in construction industry. The similarity of them is the use of Building Information Modelling in order to support integrated practice. Nevertheless, one should notice that, it is possible to achieve Integrated Practice without using BIM (AIA, 2007). On the other hand, the application of Building Information Modelling could be expand in many ways and its use to support integrated practice could be one of them which have been explained earlier. It is therefore, important to discuss the basic concept of Building Information Modelling so the potential of it can be identified. To start with, the next section will discuss about the definition of Building Information Model and Modelling, followed by its concept, nature of information, its benefits and finally, the conclusion.

3.0 DEFINITION OF BUILDING INFORMATION MODELLING

In the context of application within construction industry, it is really important to understand the definition of Building Information Model and Building Information Modelling. According to Kymmel (2008), Building Information Model is a virtual representation of a building, potentially containing all the information required to construct the building, using computers and software. The term generally refers both the model(s) representing the physical characteristics of the project and to all the information contained in and attached to the component of theses model. A BIM may include any of or all the 2D, 3D, 4D (time element-scheduling), 5D (cost information), or *n*D (energy, sustainability, facilities management, etc., information) represents of a project. Then, the definition of Building Information Modelling is further explained as a tool that may help in achieving the team's project goals and the BIM itself, however, should not be the final goal as it really is a tool. In this context, the building information modeling is defined as the act of creating and/or using a BIM.

In the context of Building Information Modeling as a tool, the concept is also supported by AIA where according to AIA (2007) Building Information Modeling (BIM) is defined as a digital, three-dimensional model linked to a database of project information. It is identified as one of the most powerful tools to support IPD. Because BIM can combine, among other things, the design, fabrication information, erection instructions, and project management logistics in one database, it provides a platform for collaboration throughout the project's design and construction.

While on the other hand, Eastman et. al (2008) argued that BIM is just a software or tool. In their context, Building Information Modelling is defined as a modelling technology and associated set of processes to produce, communicate, and analyse building models. Building information modelling is a verb to describe tools, processes and technologies that are facilitated by digital, machine-readable documentation about a building, its performance, its planning, its construction and later its operation. Therefore BIM describes an activity, not an object. In this context, building information model on the other hand, is the result of the modelling activity and further explained as a digital, machine-readable record of a building, its performance, its planning, its construction and later its operation.

And according to Hardin (2009), Building Information Modelling is just not a tool but it is a process and software which agreed with Eastman et. al (2008). This is supported by the explanation that "many believe that once they have purchased a license for a particular piece of BIM software, they can sit someone in front of the computer and they are now doing BIM. What many do not realise, though is that building information modelling means not only using three-dimensional modelling software but also implementing a new way of thinking. In my experience, as a company integrates this technology, it begins to see other processes start to change. Certain processes that have made perfect sense for CAD-type technology, now do not seem to be as efficient. As the technology changes, so do the practices and functions of the people using the technology."

To support Building Information Modelling as a process, Smilow (2007) identified several issues of implementation and they are :

a. BIM standards are not fully defined.
b. The multiple BIM products do not have the ability to communicate with one another.
c. New methods of team collaboration require new definitions for individual responsibility and liability.

d. Legal ownership of collaborative digital models must be defined.
e. Increased dimensional responsibility for the design team results in additional legal liability.
f. Expedited processes reduce the time for the customary process of "checks and balances."
g. How does the new BIM process change financial compensation for the design team?

Most of the issues, listed are related to the process in Building Information Modelling and it requires change to the current process in order to gain maximum benefit of applying Building information Modelling. Therefore, it can be concluded that Building Information Modelling is a process and not just simply a piece of software or tool.

4.0 THE CONCEPT OF BIM

According to Smith (2007) the concept of Building Information Modeling is to build a building virtually, prior to building it physically, in order to work out problems, and simulate and analyze potential impacts. The heart of Building Information Modeling is an authoritative building information model. While according to Kymmel (2008) virtual building implies that it is possible to practice construction, to experiment, and to make adjustments in the project before it is actualized. Virtual mistakes generally do not have serious consequences provided that they are identified and addressed early enough that they can be avoided in the actual construction of the project. When a project is planned and built virtually, most of its relevant aspects can be considered and communicated before the instructions for construction are finalized. It is like running a simulation of construction project by considering all aspect of construction life cycle.

In term of the types of information or data that can be derived within Building Information Model, Elvin (2007) explain that Building Information Model could provide 2-D and 3D drawing with nongraphical information including specifications, cost data, scope data, and schedules. Most importantly, it creates an object-oriented database, meaning that it is made up of intelligent objects, for example representation of doors, windows, and walls which capable of storing both quantitative and qualitative information about the project. So, while a door represented in a 2D CAD drawing is just a collection of lines, in BIM it is an intelligent object containing information on its size, cost, manufacturer, schedule and more. But BIM goes beyond further by creating a relational database. This means that all information in the BIM is interconnected, and when a change is made to an object in the database, all other affected area and objects are immediately updated. For example, if a wall is deleted, a doors and windows within the wall are also deleted, and all data on project scope, cost, and schedule are instantly adjusted.

To extend the application of Building Information Modeling to integrated practice in construction, according to Eastman et. Al (2008), building information model should be used as a building model repository. A building model repository is a database system whose schema is based on a published object based format. It is different from existing project data management (PDM) systems and web-based project management systems in that the PDM systems are file based, and carry CAD and analysis package project files. Building Model repositories are object based, allowing query, transfer, updating and management of individual project objects from potentially heterogeneous set of application. In this application, building model repository will be a central of information where each project participants are oriented to a single source of information.

Information in BIM, according to Hardin (2008) can be both visual and database driven. The concept of linking the visual representation with the spreadsheet, quantity, or other data source, it is associated with is being pushed further into the realm of open-ended systems. The concepts of open source programming or interoperability is part of the driving force behind the national institute of building sciences (NBIS) and other organizations' efforts to allow software to talk with each other and for software companies to allow for customization and application development. Figure 1 below, summerised the concept of building information modeling where in the Building Information Modelling, each project participant will share a single source of information.

Figure 1 Conceptual Diagram to Describe the Building Information Modelling Concept

Eastman et al. (2008) further explained that, in order to understand Building Information Modelling, the concept of parametric object is important in order to differentiate it with traditional 2D. The parametric BIM object are defined as:

a. Consist of geometric definition and associated data and rules
b. Geometry is integrated non-redundantly, and allows for no inconsistencies. When an object is shown in 3D, the shape cannot be represented internally redundantly, for example as multiple 2D view. A plan and elevation of a given object must always be consistent. Dimensions cannot be fudged
c. Parametric rules for objects automatically modify associated geometries when inserted into a building model or when changes are made to associated objects. For example, a

door will fit automatically into a wall, a light switch will automatically locate next to the proper side of the door, a wall will automatically resize itself to automatically butt to a ceiling or roof, etc.

d. Objects can be defined at different levels of aggregation, so user can define a wall as well as its related components. Objects can be defined and managed at any number of hierarchy levels. For example, if the weight of a wall subcomponent changes, the weight of the wall should also change.
e. Object rules can identify when a particular change violates object feasibility regarding size, manufacturability, etc.
f. Objects have the ability to link to or receive, broadcast or export sets of attributes, eg. structural materials, acoustic data, energy data, etc. to other application and models.

The ability of the objects to link to or receive sets of attributes is the main advantage of Building Information Modelling in order to support integrated practice in construction. Unlike other approach where integration is based on document level, Building Information Modelling provide channel for integrated practice by linking the practice in the level of data and information. To some extends, it integrates other dimension into the 3D model such as time dimension (schedule) and cost dimension which known as 4D and 5D modelling respectively. Once the data and information is integrated, then it is possible for the construction practitioner to work as a single entity as their information is tied together. The next section will discuss further on the nature of information that contained in the Building Information Modelling.

Theoretically, building information modelling is targeting to provide a single building model where every single project participant can refer to. However, according to BIM guide for contractor (2007) one of the earliest lessons learned is that there is rarely one model. In fact, on many projects the use of BIM can be as basic as the availability of a 3D model produced by one or more of the specialty contractors or suppliers, such as the steel fabricator or mechanical contractor. It is not unusual, particularly while the 2D conversions continue to be the norm, for multiple models to be made available on the same project. The good news is that there are software applications that can now combine models produced in different design packages and into one file, to be viewed as one composite model**.** This is where the low-hanging fruit of visualization and conflict detection can be found. This is just one of many examples of lessons that contractors using BIM have learned. The types of model and the parties responsible producing the models can be summerised as follows (Figure 2):

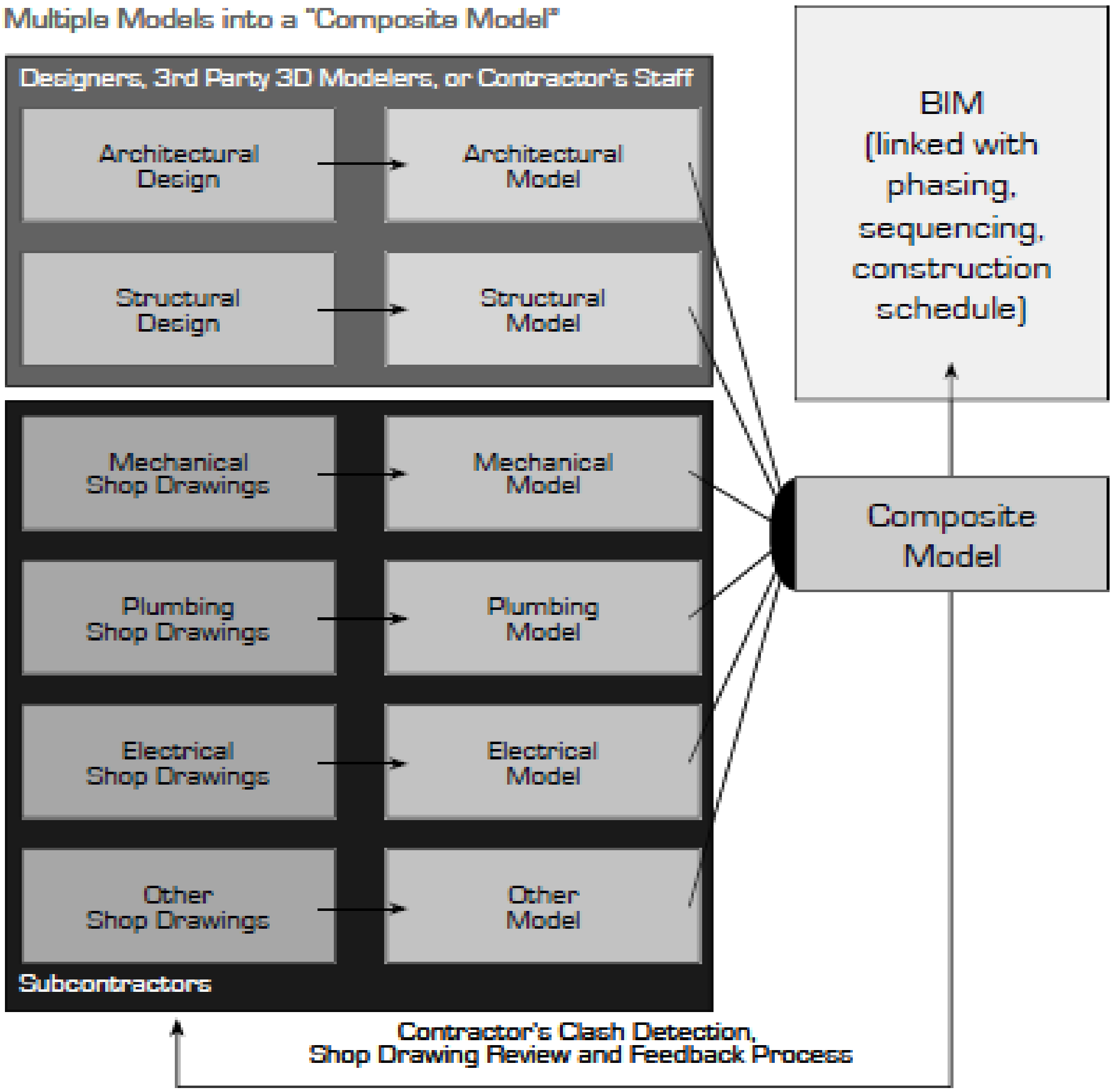

Figure 2 : Multiple Model in Implementing Building Information Modelling For a Single Project

5.0 NATURE OF INFORMATION

Kymmel (2008) identified several nature of information within Building Information Model. This pertains to all information that is part of, or connected to, the components as well as the physical information inherent in the model itself such as size, location, etc. It is important that all information required making an actual analysis from the BIM. The nature of information can be summerised as follows:

Component Information
Component information is the most basic information, contained in the 3D model file. It is primarily visual information and resides in the nature of the model part itself. Components in a 3D model also have specific locations in relation to an origin and to one another. Example of component information is a wall with material information or quantitative information such as area, volume and etc.

Parametric Information
Parametric Information is editable information contained in the parametric object. This is not an external source of information—it is embedded in the object, and therefore the model. Some of this information will be visual, while much of it can also be intellectual, such as part numbers, or material-related qualities, such as density (providing weight based on the geometry of the object), *R* value, etc.

Linked Information
Linked Information refers to information that is actually not part of the model, but is connected to the model through visible or invisible links. Visible links can be “flags” that will open a window or file when clicked to display that file, invisible links could be, e.g., connections to a database with cost information. When two files are linked, changes in one will result in adaptations in the other linked file, and vice versa.

External Information
External Information refers to information that is generated separate from the BIM, such as a construction schedule, manufacturers’ specifications of products, etc. External information may be linked to the model or remain autonomous. It is possible to provide a reference to a catalog without creating a link to an electronic file. Since not all information will be available in a compatible format, it may necessary to keep it accessible in printed form, as an external reference.

6.0 BENEFIT OF USING BIM.

There are numerous benefits that could be gained by implementing Building Information Modelling in the project, whether it is used as an isolated application or collaborative application. According to Kymmel (2008), the clearest benefit from BIM is that a 3D model improves the ability to visualize (understand) what is being presented. Many persons have difficulty understanding 2D drawing and according to Lee et al. (2003), it is estimated that 98% of the industry cannot understand drawing. While according Eastman et al (2008), the 3D model generated by the BIM software is designed directly rather than generated from multiple 2D views. It can be used to visualize the design at any stage of the process with the expectation that it will dimensionally consistent in every view. While according to Manning and Messner (2008), based on the case study of implementing building information modeling for programming of healthcare facilities, the major benefit of 3D visualization is that it could be quickly evaluated by technical and non technical staff alike. As a consequence of the clear understanding through visualization, the project could reduce the total Request of Information during project implementation. In the case study carried out by Khanzode et al (2008), only 2 of 233 RFIs identified on the project were related to field conflict and construction related issues, and these two RFIs were for systems that were not modeled using BIM tools.

Meanwhile, according to Eastman et al. (2008), BIM technology facilitates simultaneous work by multiple design disciplines. While collaboration with drawing is also possible, it is inherently more difficult and time consuming than working with one or more coordinated 3D models in which change control can be well managed. This shortens the design time and significantly reduces design errors and omissions. It also gives earlier insight into design problems and presents opportunities for a design to be continuously improved. This is much more cost effective than waiting until a design is nearly complete and then applying value engineering only after the major design decisions have been made. Kymmel (2008) then further explains that early collaboration has large benefits for the planning and construction of a building project thus the development of a virtual model is one of the best means of ensuring early and in-depth collaboration of the project team on most relevant planning, design, and construction issues. In the study conducted by Manning and Messner (2008) on the project using BIM tools and collaborative project delivery approach, the team was able to save USD 9 million and 6 months as compared to traditional process. In addition to collaboration, subcontractors were involved sooner and are resolving issues in the design and detailing stage that would typically come up in the field. It was noticeable that a lot of reciprocal work that typically happens during construction has happened during design on the project, resulting in more efficient construction.

Another benefit that could be generated by implementing Building Information Modelling is design errors and omissions can be discovered before construction. According to Eastman et al. (2008), design errors caused by inconsistent 2D drawings are eliminated in building information modelling because the virtual 3D building model is the source for all 2d and 3d drawings. In addition, because systems from all disciplines can be brought together and compared, multi-systems interfaces are easily checked both systematically (for hard and soft clashes) and visually (for other kinds of errors). Conflicts are identified before they are detected in the field. Coordination among participating designers and contractors is enhanced and errors of omission are significantly reduced. This resulting to the acceleration of construction process, reduces costs, minimise the likelihood of legal disputes and provide a smoother process for the entire project team.

The next benefit of implementing Building Information Modelling is the ability to synchronize design and construction planning. Based on the study conducted by Ting et al. (2007), the study showed that the 4D modelling enables the users to visualize the constructability of the proposed construction approach. The system also assists the project team to design a precise construction schedule so as to remove any potential unproductive activities. The result of the study is similar to the result from Koo and Fischer (2000). In the study, the 4D models able to identify and eliminate the construction related problems before going to site. It further investigated whether 4D could help project participants identify problems that would normally be overlooked in traditional bar chart techniques. The work concluded that 4D models communicate a schedule more clearly and enable even relatively inexperienced construction professionals to identify problems. The identification of problems before materialising could help companies save time and money in the long term. In developing 4D modelling, according to Kymmel (2008), the construction schedule can be developed if a preliminary schedule is available and a schematic construction sequence can be simulated. The 4D modelling could facilitate the visualization of the construction process and allow the consideration of alternative approaches to sequencing, site layout, crane placement, etc., during construction process. Eastman et. Al (2008) then further explain that this graphic simulation provides considerable insight into how the building will be constructed day-by-day and reveals source of potential problems and opportunities for possible improvements which agreed with the case study conducted by Huang et al. (2007) and Koo and Fischer (2000)

In the white paper by autodesk, the implementation of BIM could potentially reduce the construction cost. Manning and messner (2008) identified that sections, perspectives, plan views and quantity take offs could quickly (in many cases automatically) be updated to effectively ascertain potential costs. Another way of BIM could reduce construction cost is by having minimum change order during project execution. According to Khanzode et al. (2008) there are zero change orders related to field conflicts on the case study project. The project is now complete and the building is operational with 100% of MEP systems installed. There has not been a single change order due to a field related conflict. Interviews were also been conducted to the project team to determine how much they would normally expect to spend on change orders on a similar size project and the estimate was about 1% - 2% of cost of MEP systems. On this project this is a substantial savings for the owner.

7.0 CONCLUSION

For the purpose of assisting integrated practice in construction, Building Information Modelling could provide a good platform whether it is taken as tools or as a process and concept. The nature of the technology which has the ability to link to or receive, broadcast or export sets of attributes, to other application and models has attract many efforts to extend the use of it. To gain the benefits of the technology, however, require changes to some or perhaps the overall process in current practice and it is really important for the company to be aware and ready to accommodate the change.

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