BULDING INFORMATION MODELING (BIM) IN DESIGN STAGE TO ASSIST IN TIME, COST AND QUALITY IN CONSTRUCTION INNOVATION

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***Abstract*—Fragmented and complex nature of construction, leads to many problems which arises everyday during the process of construction. Therefore there is always a greater need for improving the entire construction process such as buildings of better quality, reduce cost, minimization project time and improve productivity. Within the construction phase, many problems and errors occur in the design phase. A relative new technology that is progressively getting accepted in the construction industry is Building Information Modeling (BIM), which has been playing a major role on improving construction management background. BIM is a process of virtual design in the construction of a project. This paper describes an application of new technology in design-construction interface. This study comprised: interviews with experts, data collection from several projects and design and implementation of improvement tools. The analysis results establish that both Architect and Consultant firms had realized the importance of design stage during the start up of the construction. They have accepted that BIM is the future. In the future, as the cost to build is reduced through increased efficiencies and reduction of waste via BIM. As a final thought, the idea that BIM is a one stop solution, compared to what current systems are capable off.**

Keywords—Building Information Modeling (BIM); Design Stage; Minimize Project Time; Reduce Cost; Better Quality; Improve Productivity.

I. Introduction

Construction sector is one of the crucial parts of most countries economy. Rapid growth of construction industry in Malaysia is becomes one of major industry contributing significant growth to socio-economic development. Even though spending a lot of money in construction, the industry is facing a lot of challenges such as delay to complete the project on time, expenditure exceeding the budget, construction defects and dependency on foreign workers (1).Time, cost and quality are the indicators for measuring construction project success and these three parameters are called as the Iron Triangle important phase is usually carried out with little interaction between the construction and design teams causing many problems during construction such as, incomplete designs, change orders, rework and construction delays (2). One of the common problems is project delay resulting in time and cost overruns,

disputes, arbitration, and even total abandonment (2). More than 90% of the projects experience delays resulting a significant amount of time and cost overrun (3). Time and cost are the two major elements in project management, apart from quality and scope. One of the biggest challenges in construction project management is to ensure that the project is completed on time and within estimated cost. Time and cost are the major concern to most clients/ owners and subject of continuous discussion and research. Research highlights that 9 out of 10 infrastructure project fall victim to cost escalation; 45 % for rail projects, 34% for fixed links (like bridges and tunnels) and 20% for road projects (4).

The cause is partly due to changes in scope. "*More than 70% of projects fail".* Performance improvement opportunities in construction can then be addressed by adopting management strategies. Building Information Modeling (BIM) has been playing a major role and improving construction management setting. BIM not only helps to reduce this waste and inefficiency but also helps in reducing the potential for litigation (5 & 6). Therefore, the aim of this paper is to introduce a best alternative way to improve time, cost and quality for construction innovation in the construction industry by taking advantage of Building Information Modeling (BIM) tools. The objectives of this research are, to identify the problems of design stage that currently exists in construction projects in time, cost and quality and to determine the benefits that can be obtained by using BIM tools to achieve construction innovation in design phase.

II. METHODOLOGY

The methodology selected for this research is that of qualitative method approach. This includes: interviews and observation. A total of eight people were interviewed. Though most of the professionals interviewed were from Kuala Lumpur, three of the architects practiced in Johor Baharu. The location of practice should not make any difference in the results. The method consisted of interviews with working professionals who had either used BIM in the past or were working on projects that used BIM currently. This method was adopted to find the perspective view of these professionals based on their experience and identifying benefits for future improvements. As well as information on how BIM has been implemented and improved time, cost and quality management in the design phase in civil projects and what can be learnt from that process. On the subject of BIM, noted that the amount of empirical data collected was not keeping pace with the rate of BIM implementation, perhaps due to the difficulty of quantifying the effects and benefits BIM has on the construction industry (7). The limited use of BIM in Malaysia to date means there are too few project examples to study, to be able to develop any meaningful quantitative data on BIM's effects on project key performance indicators. Due to the limitation of BIM used in the Malaysian construction industry, quantitative data can be only review on certain factors.

A. Time management

Realistic 'construction time' has become increasingly important because it often serves as a key benchmark for assessing the performance of a project and the efficiency of the contractor (8). The use of tools that can handle 3D computer object has doubled by architects and increased with over 30% by technical consultants (9). In the current situation all participants in the project use a common database to store drawings and exchange information with each other. In conventional method (2D) "plain old" hidden lines views but in Revit Architecture colour settings being done and leaving the visualization studio to focus on the high quality presentation material needed for reviews, approvals and marketing the project save time. The platform from Revit linked to the visualization of 3D StudioMax that minimizes the time required to coordinate the architectural design and visualization (10).

B. Cost management

Cost overrun is a main problem in project development and is a regular feature in construction industry but it is not as much of effective compared to time management (11). The categories of a project cost management are project resource planning, cost budgeting, cost control and cost estimating. It may be very simple or extremely complex when managing the cost of project. In project management, it should also consider the needs of project stakeholders in the project cost (12).

C. Quality management

The importance of quality management is quite noticeable in project management literature (13). Quality of construction projects is linked with proper quality management in all the phases of project life cycle (14). In the project life cycle, design and construction are the two important phases of which affect the quality outcome of construction projects significantly (15). NEDO (National Economic Development Office), a survey in London had found

that combination of "design" and "poor workmanship in the construction process" contributes more than 90% of the total failure events. The cost of the design phase accounts for only about 3-10% of the project on average, most of the research into and discussion of the quality of construction projects have focused on the construction phase, and seldom on the design phase. Quality during the design phase has great impact on later expenditures (14).

III. Issues of construction project management

Projects are defined by the need to complete a task on time, to budget, and with proper technical performance and quality. A major criticism facing the Malaysian construction industry is the growing rate of delays in project delivery. Time overrun and cost overruns factors have contributed to the high cost of construction in many countries for many years (16). When projects are delayed, contractor and the project owner have their duration extended away from the scheduled completion date. It causes affecting construction cost overrun.

Therefore it has been estimated that 33% of on-site construction waste is a direct result of the architect's failure to implement waste reduction measures during the design stage with initial design decisions potentially accounting for one third of all waste production throughout the lifetime of a project (17).

The lack of project pre-planning, uncertainty or lack of clarity concerning project process integration were also leading to misinterpretations and miscommunications of project results and needs issues (18). A centralized decision-making process and lack of delegated authority to field personnel often hindered progress and communications at critical emergency response and recovery stages (19). Design fees are often less than one percent of the life-cycle cost of a project, yet the design is one of the most important factors influencing the construction cost.

IV. BIM Technology in design stage

There are many uses of BIM for each project participant. During the design phase, the use of BIM can maximize its impact on a project since the ability to influence cost is the highest. The team can creatively come up with ideas and provide solutions to issues before problems become high cost impacts to the project. This can be realized through the cooperation and coordination of the entire project staff. Therefore, it is extremely important to have a good collaboration. The use of BIM especially enhances the collaborative efforts of the team. The architect and engineer can test their design ideas including energy analysis. The construction manager can provide constructability, sequencing, value and engineering reports. They can also start 3D coordination between subcontractors and vendors during early stages of design. The owner can visually notice if the design is what he is looking for. Overall, the BIM promotes the collaboration of all of the projection participants.

A. BIM in Time

1. Design Reviews

One fundamental and important issue that continues to outbreak construction projects and contributes to cost and schedule growth is design changes and errors (20). In addressing the issue, it has been proffered that BIM technology will significantly improve the efficiency and effectiveness of delivery processes and the constructed facility (21). Below are the discussions on design reviews, this can eliminate construction issues early in design and significantly reduce requests for information, change orders, team conflicts and rework.

2. Faster and more effective processes

According to the survey conducted by McGraw-Hill constructions, more than 48% of the owners say that overall project outcomes are of high benefit. There are very few RFI's and field coordination problems. BIM helps transfer information easily. It can be more value added and reused (22). Also BIM helps in quickly reacting to design or site problems (5).

3. Early check against and reducing rework in design intent

BIM not only provides 3D visualization but also quantifies material quantities. This helps in accurate and early cost estimating. Hence the design intent of a building both quantitatively and qualitatively can be checked early in the process (5). The problems are fixed early in the design and hence there will be fewer issues in the plans (23). Any design changes entered to the building model is automatically updated. Hence, there will be less rework due to possible drawing errors/omissions (5).

More than 80% of the people agreed that reducing rework is very important and BIM helps in achieving it (23). Therefore using of BIM can focus on behaviour and methods of working during all

phases of a project's life cycle so as to reduce opportunities for human error and reducing rework (20).

4. Detection of errors and omissions (Clash detection)

This is the most rated way by which owners save time and money using BIM (23). In 2D drawings, any changes in one drawing are not updated in other related drawings. This leads to many inconsistency and hence lots of errors and omissions. Lots of these errors is detected only after the work has started at the site, which might lead to many site conflicts, legal disputes and change orders. However, use of BIM eliminates these issues. Conflicts are identified before they are detected at site and hence coordination between the designers and the contractors are enhanced. Detection of errors speeds the construction process, reduces costs, minimizes legal disputes and provides a better project process and (5). Though the use of BIM, it helps to eliminate these types of errors from occurring through the in-built clash detection check (5).

5. Better Collaboration

The purpose of collaboration is to integrate the separate knowledge possessed by the participants in the design process into one meaningful whole (24). One of the disciplines greatly benefitting from BIM are MEP Designers and Engineers. The use of BIM makes visible the connections between project participants, but different to people belief it does not faster collaboration between them (25). New technologies such as BIM have the power to disrupt 'shared frames of reference' by making explicit power struggles among different professional groups (25).

B. BIM and Cost

Project savings are considerably high if the BIM is used during the early design phase. This is mainly due to coordination efforts that yield to minimization of trade conflicts in the field.

1. Construction and Fabrication

Using 4D BIM it is possible to simulate the construction process, visualize how building will be constructed day-by-day, and reveal potential problems on the site and opportunities for improvements (25). BIM technology allows identify clashes between systems from different disciplines before construction takes place. It also facilitates fabrication process. 3D elements from the model can be sent to factories where element production process is fully automated (24).

2. Take-offs and Estimating

The model contains information, or can link to information, necessary to generate bills of materials, size and area estimates, productivity; materials cost, and related estimating information. It avoids the processing material take-offs manually thus reducing error and misunderstanding (5). Moreover, the linked cost information evolves in step with the design changes. The estimating advantages are so significant that some contractors will create models on 2D designed projects to use the model's estimating capabilities (5). With the use of software such as Revit, exact material quantity schedules will be easily maintainable and are in general much more accurate than a human trying to quantify the materials of the same project. Not only the schedule accurate, but any changes to the digital model will also be updated, in the schedules much quicker and more efficiently than in CAD. Other than that visualizing all the items being taken off reduces the chance of the estimator missing items. It also reduces the chance for transposition errors as the design changes the linked model updates the estimated quantities (26).

C. BIM and Quality

1. System Coordination

After all building systems are detailed in 3D and incorporated into BIM, these systems are then coordinated. All equipment, fixtures, pipes, ducts, conduits, structural members, and other building components are checked through "clash detection" tools to discover and resolve conflicts before systems are installed in the field. Some early cases have shown an 80% reduction in field-related questions and conflicts due to this specific use of BIM.

2. Daylighting

BIM tools, such as Autodesk's® Revit®, can provide information for energy analysis. These tools can be used to evaluate lighting design and options, in conjunction with their material take-off capabilities, and can generate necessary documentation for LEED™ certification (27). Revit Building changes by allowing the design team (rather than expensive lighting labs) to undertake the modelling, measurement, and documentation of complex interior daylighting within their standard design environment (28). Ecotect Analysis can be used again to rearrange rooms and zones, to size and shape individual apertures, to design custom shading devices, or to choose specific materials based on environmental factors such as daylight availability, glare protection, outside views, and acoustic comfort (29).

3. Energy Analysis

BIM tools open up new possibilities to analyze the energy efficiency of buildings at the design phase. With the help of 3D models, BIM tools provide the support necessary to analyze a building's energy efficiency in order to optimize its performance (5). Simulations of the building's energy efficiency allow the project stakeholders to examine the optimization of many features, including:

- The building's orientation to maximize solar gains (heat and natural light)
- The fenestration percentage and its direct impact on energy costs
- The choice of insulating materials for the building envelope
- The choice of HVAC systems

In addition to facilitating the decision-making process, this analysis is very useful when evaluating design scenarios according to specific energy criteria. It is also possible to animate solar studies for a defined period. Environmental performance and life cycle costs are more predictable and better understood (22).

4. 3D Coordination

3D BIM model is that BIM consists of intelligent objects which are able to hold information which automatically can be updated and modified with the progress of a project (30). The 3D coordination can be started right after the model is created to ensure that any same space interference (hard clash) or clearance clash (soft clash) conflicts are resolved. When drawing in 3D CAD application, the model is made of multiple files, storing each floor. In a BIM application the model is stored in one file. When one or more people are working on one model, there is a need to define who has access to what in the model. Version control and updates need to be maintained on the model. It is also possible to check out one object, e.g. wall, edit the object and check it back into the model. Meanwhile others cannot edit that particular object.

V. Discussion

The result of the data gathered from the interviews, is clearly indicate the problem faced by the consultants and architects during the design stage. Both Architect and Consultant firms had realized the importance of design stage during the start up of the construction. However when there is an effect on time in the design process, consequently the cost and quality of the construction are also affected. Therefore, all the respondents had agreed that conventional method where it is in 2D drawing would not be visualize clearly and due to it a lot of design problems are still arising in the construction industry. This study shows that the most of the construction industries are still implementing AutoCAD, this is because of its popularity and availability personnel in the local market compared to the BIM tools. Most of the respondents agreed that by adopting BIM tools, a firm could reduce the problems in design stage. Besides that, hiring a competent person where he or she is an expert in the design. In addition, technology improvement on the design process shall be implemented by consultant and architect firms.

Innovation in construction started from the design phase and to archive this innovation the consultant and the architects shall practice BIM by adopting the tools as a new technology method for construction in the design stage. BIM is one of the key innovation tools currently in this new technology, but most of the Malaysian construction industries either avoiding this innovation or stubbornly trying to use the conventional method due to the few major factors effecting the technology transformation in the construction industries. The government targets set for 2016, that all appropriate construction projects will use BIM, affirms a certain confidence in the widespread use of the method across the industry. Architect and consultants believes that the use of BIM will reduce cost and add long-term value to the development and management of built assets in the construction sector. Better design is produced in a short time period with faster and more effectiveness process by early check against in the design stage.

Although BIM is an innovative approach to the construction technology but it also reduces the cost of the construction by triggering the problem at the early stages. BIM not only reduces costs by increasing collaboration between the design team, but it will also provide future building visualization more clearly to the client to manage their understanding of the building design. Besides than that, BIM increase collaboration, better coordination of drawings, the sharing of information, better predictability of building performance direct the clients to save on the cost in construction enviroment. Further more, produce by BIM models are quality compared to the conventional method which only leeds to shakeholders own imagination.

VI. Conclusion

The positive effect of BIM on the construction industry as a whole is almost unquestionable, ‘To BIM or not to BIM’ is not so much the question, but there are a number of issues which need to be overcome. Architects have accepted that BIM is the future, but how, when and what to adopt is up to the individual firms to decide. The issues that have been

mentioned in this study, mainly involving collaboration, are ideas which have been debated for years, holding the industry back and maintaining its 'blame culture' characterisation.

Since BIM technology is still been adopting, designers or architects may not provide sufficient information such as material information on the BIM model during the design phase; thus the generation of bill of quantities will also be insufficient. As the design technique in BIM becomes mature and more predefined BIM models will become acceptable, the design in BIM might be able to conclude sufficient information at the early stages of the building lifecycle. By then, owners and even contractors can track a more accurate cost of the project at the early stages of the project lifecycle and ensure the cost will be kept within the budget.

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