THE IMPACT OF BUILDING INFORMATION MODELING (BIM) TO ARCHITECTURAL DESIGN PROCESS

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DEDICATION

This thesis is dedicated to my parents, who taught me that the best kind of knowledge to have is that which is learned for its own sake.

I would like to dedicate this thesis to my loved Mr. Sathis Kumar.
I always love you for who you are and all the support that you had given me throughout all the years that I have been in the university.

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May god bless all of us.

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ABSTRACT

Design in architecture is one of the most diverse activities considered by all related parties in construction industry. During the construction design process, many problems and errors such as design changes & rework, incomplete design, standard of quality in drawings and technical specifications, lack of communication, delays in the drawings, mistakes and errors are arising from this industry day by day. This research has been conducted with the aim to establish the contribution of Building Information modeling (BIM) on architectural design process. The objectives of this research includes, to recognize and examine the current conventional design problems in construction projects in terms of time, cost and quality and to recommend the benefit that is obtained by using BIM technology in the architectural design process. This research was conducted by using qualitative method where experience architects whom are currently implementing BIM in their firms was been interviewed. The feedback and results obtained from the interview were analyzed by using Microsoft Excel. Quota sampling method was used in selecting the respondents, which consists of 8 architects implementing BIM. The analysis results shows that, architect realize the problems and suggested the solutions based on their experience in handling several of projects by using the conventional method. It also shows that, BIM is the future tools for 3D design since it integrate all the design documents, the drawing are well interpreted and the designer easily viewable compared to conventional method. It is important, architects need to present their design in 3D drafting to create a better visualization to the client. Adoption of BIM should be implemented from the early process in order to manage construction project effectiveness.

ABSTRAK

Rekabentuk adalah salah satu aktiviti yang paling penting dititikberatkan oleh semua pihak yang terlibat di dalam industri seni bina. Semasa fasa pembinaan, kebanyakan masalah yang sering berlaku seperti perubahan rekabentuk dan pembaikan semula, rekabentuk yang tidak lengkap, tahap kualiti lukisan rekabentuk dan spesifikasi teknikal, kurang komunikasi, kelewatan dalam penyiapan lukisan dan kekangan yang meningkat dalam industry ini dari masa kesemasa. Tujuan kajian ini adalah untuk mengenalpasti kebaikan pengunaan "BIM" dalam proses rekabentuk pembinaan. Objektif kajian ini adalah untuk mengenalpasti masalah yang wujud di fasa rekabentuk dalam sektor pembinaan yang sedia ada dari segi masa, kos dan kualiti serta mengkaji cara pengurangan masalah dalam fasa rekabentuk dan mencadangkan faedah yang boleh diperolehi melalui pengaplikasian "BIM" dalam fasa rekabentuk bangunan. Kaedah metodologi yang digunakan dalam kajian ialah melalui pendekatan kualitatif. Maklum balas dan keputusan yang diperolehi melalui temubual telah dianalisiskan dengan menggunakan "Microsoft Excel". Kaedah persampelan kuota digunakan untuk memilih responden arkitek seramai 8 orang yang menggunakan "BIM". Hasil kajian telah menunjukkan pihak arkitek menyedari dan memberi cadangan mengikut pengalaman mereka dalam pengedalian sesebuah projek pembinaan dengan menggunakan sistem konvensional. "BIM" adalah alat rekabentuk maya 3D masa depan kerana ia dapat mengintegrasikan semua maklumat projek serta boleh dipraktikan dalam sektor pembinaan berbanding dengan sistem konvensional yang sedia ada. Cadangan kajian ini adalah, arkitek perlu membentangkan rekabentuk mereka didalam paparan 3D supaya pelanggan dapat memahami reka bentuk tersebut. "BIM" seharusnya dilaksanakan dari proses permulaan supaya pengurusan effektif projek pembinaan dapat dilaksanakan.

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LIST OF ABBREVIATION

BIM	-	Building Information Modeling
IPD	-	Integrated Project Delivery
AEC	-	Architecture, Engineering and Construction
NIBS	-	National Institute of Building Sciences
CAD	-	Computer Aided Design
DOD	-	Department of Defense
DED	-	Department of Energy
RFI	-	Request for Information

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CHAPTER I

INTRODUCTION

This chapter provides general introduction for this thesis. It begins by discussing the subject matter of the research by highlighting the main issue under exploration and providing a background to explain it. This aspect culminated in the problem statement of the research. The next main section addresses the purpose of the thesis by explaining the main aim and objectives of the research. It also outlines the key research questions that guided the inquiry. The next section indicates the scope and limitation of the thesis. It describes the key elements considered in the research and the geographic area to which the research is confined. It then indicates the limitations of the research in terms of time and those relating to data collection. This followed by briefly addressing the scientific relevance, applicability, societal relevance and use and the methodology of the research. Finally, the organisations of research was described.

1.1 Background of Research

Rapid growth of construction industry in Malaysia becomes one of the major industries contributing significant growth to socio-economic development. The Architecture/Engineering/Construction (AEC) industry is one of the multidisciplinary domains in which collaboration among related parties is of utmost importance. With the advent of computers, many material and technological improvements have been made to building design in the last four decades and many builders and designers saw their drafting load lightened because repetitive tasks could be automated. After six centuries of manually conveying lines and texts on

paper, computers were first adopted as an aid for automating certain aspects of the design process to Computer Aided Design (CAD) systems which generate digital files. Though, conventional two-dimensional (2D) CAD technology has dominated the industry, and technological progress has been severely constrained by the limited intelligence of such applications in representing buildings and the capability to extract the relevant information from the representation that is needed for building design. Drawings are no longer done manually, but the ubiquitous use of CAD applications in creating drawings has not revolutionized the construction industry in any way. With the automation of design tasks using computers, the essential nature of documentation did not change. The same drawings and documents describing the project are still used.

Architectural design is a complex and open process. Design process starts from the abstract stage to solve a design problem until it reaches the design solution in the form of design product. Designing activities is a repetitive problem solving process (Demirkan 1998). Watanabe (1994) describes designing process as a process to fulfill human needs through new idea produced. According to French (1998), architecture design is a response to human special needs which is refuge and comfort. Lawson (1997), states that architectural design is a process where an architect produced a space, place and building which has a big amount of effects on the quality of human life. Most architects agreed with Sanders (1996) whom stated that architectural design is a repetitive process where the process scheme can be recognized, valued, repeated, explored and repaired until the best solution is achieved. Decision making activities in architectural design process happens at sketching stage, schematic design stage and final design stage. At the details stage, design process is focused on producing drawings activity and planned building construction activity.

Currently, the work within the design process is split into several temporary sequences, and it is delivered to different specialists for its execution. In building projects, first the owner selects the architects who prepare the architectural designs and specifications, then the structural design and other specialty designs are developed. Generally, in construction stage, a contractor selected by the owner, and it is deliver to different consultants for its execution.

As mentioned by Saputra *et al*. (2011), the time, cost and quality are the main indicators in measuring construction project success. An assessment needed to measure the capability to meet these three constraints before a project started. The management can set up a set of action plans in the planning and design stage as preventive or response based on the assessment results. It is in the design process where the requirements of the client are identified and the constructive aspects and the standards of quality are defined through procedures, drawings and technical specifications.

Nowadays, the AEC (Architecture-Engineering and Construction) industry is facing a technological change represented by the transition from CAD-based (Computer Aided Design) documentation to BIM (Building Information Modeling). Unlike the CAD drawings which were limited in information, BIM opens an expanded range of possibilities due to the immense amount of information which can be encapsulated and later extracted from the digital model. BIM involves representing a design as objects that carry their geometry, relations and attributes (Eastman, 2009). In addition, separate drawings for contract documents and then developing a separate set of detail drawings are consider waste.

BIM not only helps to reduce this waste and inefficiency but also helps in reducing the potential for litigation. It changes the base documentation used in building design and construction to a new representations, which are machine readable for automation as opposed to human readable for manual conducts (Smith *et al.*, 2009). Figure 1.1 shows the contents of building designs are transfer from paper to digital 2D-CAD-drawings during the 1990's. Currently we are experiencing a change from drawings towards model based technology and methods. The models produced are more friendly then conventional method. Therefore, BIM adoption is increasingly important in the construction industry (Penttila, 2009).

Therefore, this research is focus upon what is the impact of BIM on the architectural design process.

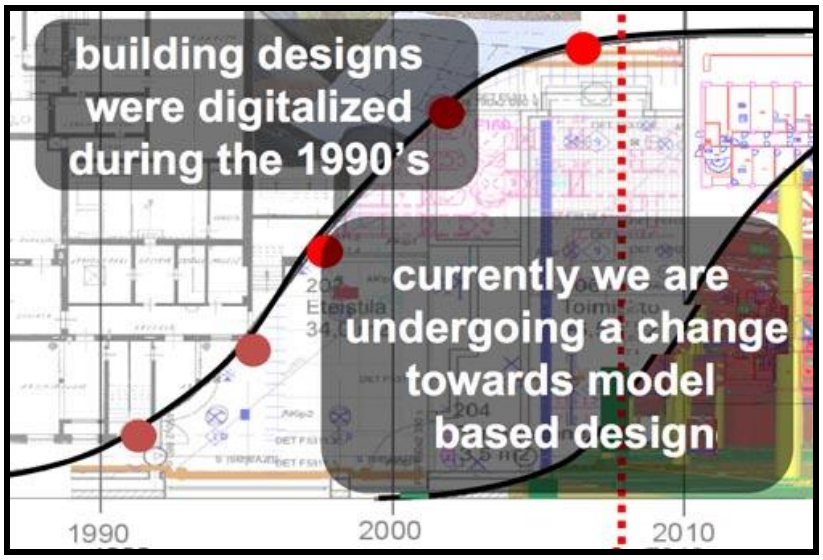

Figure 1.1: Building designs were digitalized 1990's until present (Penttila, 2009)

1.2 Problem Statement

Due to the fragmented and complex nature of construction, also many problems could arises every day during the process of construction cause by factors such as weather, material delivery delay, labour dispute, equipment breakdowns, job accidents, change orders, and numerous other conditions. Most of the people involved in the construction project are lack of communication and less interaction among the project teams directly contributes to the problem. The earlier the changes are rectified, the lesser impact it will have on the project. Furthermore, conflicts over project changes can be minimized when the problem is found at the earlier phase of the project.

During design stage usually, planners and architects work independently with little input and lack of communication with each other (Granroth, 2011). Due to this, revisions of plans and designs always occur that affect government and the private are required to have a close collaboration and working together to bring positives changes in the industry. Lerthlakkhanakul *et al*. (2008), and Autodesk (2008), state the dependency between project platforms and technical platforms saying that there is a gap in communication between architects and users. The architect fails to explain

his or her design how the design will look like after users are unable to imagine how the design will be emerged after the construction phase. In the related literature, it is also well documented that there is a lack of integration between the current computer aided design (CAD) systems (Taslı and Sagun, 2002; Hew et al., 2001). Most of the practical and exploratory CAD tools focus on single discipline or a single task in the process. Therefore, the usefulness of models should be judged not against an imaginary perfection, but in comparison with the mental and descriptive models that could be used alternatively (Radford *et al*., 1988).

The problems of this work sequence have been discussed for many years. The main problems that have been detected are the little interaction among design and construction and among the specialists, this situation compels the following phases to work on incomplete designs. The consequences are suboptimal solutions, lack of constructability and a great number of change orders (design and construction rework). The impacts of changes are not understood and rarely recognized, in terms of costs and schedule. The work hours invested by the designers in the changes have been estimated in a 40 to 50% of the total of a project (Koskela 1992). In Latin American countries, it is estimated that between 20 to 25% of the total construction period is lost as a product of design deficiencies (Undurraga 1996).

On the other hand, the problem with the traditional/conventional method is that the documents produced are same as manual and did not save the building design and construction industry from being inefficient. CAD systems did nothing to reduce errors and wastages which basically arise due to coordination problems. Though, as CAD systems were further developed, additional information was added to these systems to allow for more data and associated text. With the introduction of conventional three-dimensional (3D) modeling technologies, advanced definition and complex surfacing tools were added. Based on the previous argumentation it is clear that the design-construction interface offers a great potential for improvement.

To overcome the limitations of traditional 2D designs, BIM which is a novel technology and concept has solved many issues related in design process. To achieve this improvement it is necessary to recommend BIM technology and its benefits which have been playing a major role in improving time, cost and quality in design process.

1.3 Aim of the Research

The aim of this research is to establish the contribution of BIM on the architectural design process.

1.4 Research Objectives

The objectives of this research are:

i. To recognize and examine the current conventional design problems in construction projects in terms of time, cost and quality.
ii. To recommend the benefits that can be obtain by using BIM technology to establish the impact of BIM on the architectural design process.

1.5 Significance of the Research

Today we are in a highly competitive world as far as project performance is concerned. There is a need for construction innovation. Therefore, putting multiple efforts in vastly integrated and complementary ways to achieve this construction project success is required. This research will contribute to architects in particularly on how designers can improve their work faster, effective and quality during the design process, and identify how BIM technology can be apply in projects to realize the impact of BIM on the architectural design process. The result from this research will be useful to architects to practice the impact of BIM in early stage. The research concluded that, although BIM technology do pose some shortcomings such as interoperability issues, the use of BIM is beneficial to the construction stakeholders.

1.6 Scope of the Research

Project success is dependent on, the performance of the design team. The designers are the key players in the construction industry whose services are need from the conception stage of the project to its completion. The performance of the designers is therefore important because any decision made at the inception of the project will affect project success. According to Minato (2003), defective designs adversely affect project performance and the participants and are responsible for many construction failures. Failure at the conceptual planning and design stages may lead to significant problems in successive stages of the project. Therefore, this research concentrates on the design stage, focusing on architects in three triangle (time, cost and quality) practices. This research focuses on the participants of the construction industry, which is an architect to get their opinions towards the BIM adoption in solving the construction projects success issues. The respondents were chosen based on the top management level and the middle management only. In addition, the research will only focus on the construction firms that using BIM.

The major limitation is that the interview of this thesis is focusing on Malaysian architects firm which is regarding the use of BIM practices. Thereby the majority of architects have limited knowledge and limited practical experience on BIM issues. To set a realistic and interesting scope for this project, it was been chosen to do interviews on the design process only.

1.7 Research Methodology

This chapter describes the methodology used in this research. In this study a qualitative research method was applied and is built up by a relatively small number of semi-structured and open-ended interviews (Silverman, 2005). The qualitative method is used when there is a wish to describe things that already exists. It started by conducting the first stage of the literature review. The goal of this research methodology was to collect qualitative data that could be used to compare against findings from other research strategies. It is important to note that this research engaged two stages of literature reviews. The first stage of the review carried two

purposes as following: This approach is expected to understand and deliver the interviewees' experience, attitudes, and best practice to implement BIM in construction projects. Both Trost (2005) and Silverman (2005) emphasize the view of the reality as complex and our choice of study method as not always obvious.

After defining the interview questions and the data collection strategy, the research progressed into the data collection stage. The stage was initiated by first identifying potential representative. The identification was done by reviewing the local job advertisements on the internet and in newspapers that offered BIM related posts, direct communication with BIM tools providers, direct contact with participants and speakers in a local BIM seminar and attachment and collaboration with Construction Research Institute of Malaysia (CREAM), the research arm for Construction Industry and Development Board of Malaysia (CIDB). As a result, eight architects were identified and agreed to participate in the case study research.

Eight experts were interviewed. They were selected based on their knowledge and expertise in this field. All of the eight interviewees have a long experience in architectural practice and they are BIM users. The main techniques that were used to collect the primary data were semi-structured interviews each organization. Each interview was audio recorded using a Dictaphone. As for analyzing the data, it was firstly transcribed into an interview script before content analysis was conducted. The findings from each architect were then cross analyzed in a table of matrix form to determine the pattern of answers. After that, the second stage literature review was conducted to make sense, justify, and theoretically validate the research findings. The process flow of the research is described in chapter 3, Research Methodology Framework in Figure 3.1, Research Process Flow, as can be referred to page 64.

1.8 Organization of the Thesis

The organization of this thesis includes the following below;

Chapter I: Introduction

This chapter aims to give an overview of the thesis. This first chapter provides an introduction to the research issue. It presents a general view of the background and describes briefly the main problem and what this research aims to achieve.

Chapter II: Literature Review

This chapter consists of a literature review where major research and other relevant research with regards construction project performance, three triangles (time, cost and quality) and time management are highlight. Authors elaborate the most important parts of related theory found in academic literature and electronic sources.

Chapter III: Research Methodology

This chapter explains about the interview that have been use to carry out this research. The description of each method briefly explained in the chapter. Besides that, explains the technique used in the analysis and issues related to data collection.

Chapter IV: Problems in Design Process

This chapter explains about the first objective for the purpose of this research. Identify the problems of design stage that currently exists in construction projects in terms of time, cost and quality and identify the factors to overcome the problem in construction design stage.

Chapter V: Benefit of Using BIM in Construction Design Process

This chapter consists of the second objective. It will determine the benefits that can be obtained by using BIM technology to achieve construction project success in design process.

Chapter VI: Conclusions and Recommendations

The chapter revisits and discusses the summary of the research, the research objectives, and the research questions, presents the conclusions derived from the research, highlights the contributions, points out the limitations of the study and suggests recommendations for future research. References and appendices are presented at the end of the thesis.

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APPENDICES

Invitation for Interview Participation

Potential of BIM in Design Stage for Construction Innovation: Time, Cost and Quality"

TO WHOM IT MAY CONCERN

Dear Sir/Madam,

I am doing a research entitle "**Potential of BIM in Design Stage for Construction Innovation: Time, Cost and Quality"** in the University Tun Hussein Onn Malaysia (UTHM).

This research aims to, identify the alternative ways to improve time, cost and quality during planning and design stages in the construction industry by taking advantage of BIM technology. This research is conducted by Punitha Rajendran, a master's student of the Faculty of Technology Management & Entrepreneurship at Universiti Tun Hussein Onn Malaysia, under the Supervision of Dr. Seow Ta Wee and co-supervisor Dr. Goh Kai Chen.

Managing time well in construction organization is important to achieve cost saving, good quality of work and improve efficiency and effectiveness in construction activities. Thus, there is a need of a guideline to help in improving time, cost and quality industry by taking advantage of BIM as a tool. BIM is not just the latest release of CAD software; it is an entirely new way of looking at the design and construction of a building. Advancements in software technology lead to a new architectural drafting revolution. BIM software provides an innovative approach in developing a set of construction drawings for a building. Compared to CAD, the BIM software essentially creates a drawing for the user according to the provided input, hence the name, 'information modeling.' There are many additional advantages that BIM has over CAD software. BIM adoption is increasingly important however, current construction industry is currently facing challenges in increasing productivity, efficiency, quality and for sustainable development. It is considered as one of the most promising developments in the AEC industry.

This research can only be undertaken with your co-operation and assistance, and hence your valuable contribution will definitely be acknowledged in the thesis. The data obtained from the survey will be treated as **strictly confidential** if required and no reference will be made to companies or persons.

Thank you in advance.

Punitha Rajendran,

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INTERVIEW QUESTION
ARCHITECTS AND DESIGN TEAMS

POTENTIAL OF BIM IN DESIGN STAGE FOR CONSTRUCTION INNOVATION: TIME, COST AND QUALITY

- This research aims, to identify the alternative ways to improve time, cost and quality during planning and design stages in the construction industry by taking advantage of BIM technology.

The objectives of this research are:

i. To recognize and examine the current conventional design problems in construction projects in terms of time, cost and quality.

ii. To recommend the benefits that can be obtain by using BIM technology to establish the impact of BIM on the architectural design process.

Section A

Respondent Background Information

1. Name :
2. Company Address :
3. Off/Hp :
4. Age :
5. Current Position :
6. Experience in construction industry : _____ years
7. Academic qualifications :
8. For how long have you been in BIM practice?

Section B

This section aims to recognize and examine the current conventional design problems in construction projects in terms of time, cost and quality.

In traditional design where 2D drawings were manually generated, because this manual process was time-cost trade off problems and poor quality, therefore the architects or designers could not respond to the timeframe of design decision making.

1. Please briefly explain, what are the common problems that affect the time, cost and quality associated with traditional construction process of the design phase?
2. Based on your experience, please briefly explain on how you deal with the problems as mentioned in section B.

Examples:

i. Time

a. Mistakes in drawing preparation

Other related problems, please

specific:……..…….

……

……

ii. Cost

a. Design changes
b. Prepare separate documents for building projects

Other related problems, please

specific:……..…….

……

……

iii. Quality

a. Lack of communication between stakeholders
b. Work with 2D coordination

Other related problems, please

specific:……..……..

……

……

Section C

This section aims to determine the benefits of using BIM as a tool to improve time, cost and quality in construction design phase.

3. What BIM software do you use? Examples:

- Autodesk Revit
- Graphisoft ArchiCAD
- Bently Systems
- Digital Project
- Vectorworks
- Tekla Structures
- Navisworks
- Google Sketch Up
- Other :…….

From an Architect's point of view, what are the advantages of applying BIM in time, cost and quality? Please briefly explain.

4. With the existing BIM concept, do you think BIM can effectively improve the design process? Can you please briefly explain how?

5. How many days does it takes to prepare for the approval of drawings? Do you think it is faster by using BIM?

6. How do you detect the mistakes in construction drawing preparation? Does the BIM technology help in detecting those mistakes?

7. How do you detect errors and omissions (Clash detection in drawing)?

8. Do you think BIM can help in preparing effective design and technical review of all the projects? If yes, can you please briefly explain how?

9. By using BIM, do you think that the collaboration among project stakeholders can be improved?

10. How does BIM contribute the schedule of estimating? (Fast and accurate).

11. How does BIM reduce cost? Can you please briefly explain how? In terms of:
    i. Shop and Fabrication Drawing-
    ii. Take-offs and Estimating-
    iii. Construction and Fabrication

12. Is there BIM 3Dmodels that provide construction details and fabrication information? Is yes, does this reduces the costs?

13. How does the communication between different designers in the project?

14. How does BIM analyze the energy efficiency, day lighting and indoor air quality of buildings at the design phase?

15. What are the effects of BIM in the collaboration between stakeholders?

16. How does the project information be shared between different stakeholders?

17. Do you know about the 3D coordination in BIM? If yes, what are the benefits you have obtained from using it?

18. Do you think that BIM is a forward shift into the future of construction innovation, please do give some suggestion.

    ……

    ……

All collected data will be kept strictly confidential and anonymous, and they will be used for academic research purposes ONLY.

Thank you for completing the questions. We appreciate your time.

~End~