FEASIBILITY STUDY OF FOUR DIMENSION (4D) VIRTUAL CONSTRUCTION TOOL TO MITIGATE DELAYS DURING CONSTRUCTION

BY

JULIA MOHD NOR

A thesis submitted in fulfilment of the requirement for the degree of Master of Science (Built Environment)

Kulliyyah of Architecture and Environmental Design
International Islamic University
Malaysia

JULY 2011

ABSTRACT

The problem of delays in the construction industry is a global phenomenon and the construction industry in Malaysia is no exception. In the current day context, despite significant benefits in terms of time and cost savings gained through the systematic use of 4D technologies on construction projects, Malaysian construction industry has yet to embrace this 4D CAD technology. A feasibility study on the acceptability of 4D planning tool as a tool to mitigate delays during project control is explored among construction practitioners focussing on the construction phase of project life cycle. Surveys and semi-structured interviews were accomplished on 169 respondents comprising the clients (owners), Local Authorities or Regulatory Bodies (JKR), contractors and consultants (architects, C&S engineers, M&E engineers, quantity surveyors). The sampling method used in this study is stratified by convenience through referral networks and former project team members. Out of 164 valid samples, 50% were from C&S Engineers, 22.6% were from M&E Engineers, 17.7% were from Architects, 6.7% were from Quantity Surveyors and the remaining 3% were from others. The responses obtained from this survey indicates that about 96.3% of the overall samples acknowledges the application of this new 4D technology as a useful tool with good potential to mitigate delays in relation to visualization, analysis and communication. However, responses obtained from the semi-structured interviews indicates cost, skilled resources, mindset/ attitude and bureaucracy as factors that might hinder the application of this 4D planning tool at workplace. The top 5 common causes of project delays identified from this study are 50.3% by contractor's poor site management, 45.6% by contractor's financial problems, 45% by client's slowness in making decision, 34.9% by consultant's poor supervision and decision making and finally, 31.4% by contractor's construction mistakes and defective works. Based on the outcome of the study, it is recommended that financial and technical support be made available before its actual implementation can be realized in our Malaysian industry.

خلاصة البحث

مشكلة التاخير فى صناعة البناء والتشييد هى ظاهرة عالمية وصناعة البناء والتشيد فى ماليزيا ليست استثناء. فى السياق الحالى ، على الرغم من الفوائد ال الكبيرة من حيث توفير الوقت والتكلفة المكتسبة من خلال استخدام تكنولوجيا الابعاد الرباعية فى مشاريع البناء والتشييد، صناعة البناء والتشييد الماليزية لم تحتضن هذه التكنولوجيا. تم استكشاف دراسة جدوى بشأن مقبولية اداة التخطيط ذات الابعاد الرباعية كأداة للتخفيف من التأخير خلال مراقبة المشروع بين المهنيين الانشائيين مع التركيز على مرحلة التشييد من دورة حياة المشروع. تم انجاز استبيان ومقبلات على 169 عينة بحث تتألف من عملاء (ملاك) والسلطات او الهيئات المحلية ، مقاولون، استشاريون (معماريون، مهندسو انشأءات وتشييد، مهندسو كهرباء وميكانيكا، ومهندسو تقديرات). طريقة اخذ العينات المستخدمة فى هذه الدراسة هى العينات الطبقية المريحة من خلال شبكات مرجعية او شبكات الاحالة واعضاء سابقين فى فريق عمل المشروع. 50% من اصل 164 عينة صالحة كانوا من الهندسين الانشائيين والتشييدين، 22.6% كانوا من مهندسين الكهرباء والميكانيكا، 17.7% كانوا من المعماريين، 6.7% كانوا من مهندسين التقديرات، و3% الباقي كانوا من الاخرين. تشير الردود التى تم الحصول عليها من هذه الدراسة بأن 96.3% من اجمالى العينات يقر باستخدام تكنولوجيا اداة الابعاد الاربعة باعتبارها أداة مفيدة ذات امكانيات جيدة للتخفيف من التاخير فيما يتعلق بالتصور، التحليل والاتصالات. ومع ذلك فان الردود التى تم الحصول عليها من المقابلات تشير الى ان التكلفة، الموارد الماهرة، العقلية\التصرفات والبيروقراطية من العوامل التى قد تعيق تطبيق تكنولوجيا الابعاد الاربعة كأداة تخطيط فى مكان العمل. اعلى 5 اسباب شائعة لتأخر المشاريع حددتها هذه الدراسة هي 50.3% من قبل ادارة المقاول السيئة للموقع، 45.6% من مشاكل المقاول المالية، 45% من بط العميل فى اتخاذ القرار، 34.9% من سؤ اشراف الاستشاري وقرارته واخيرا 31.4% من اخطاء المقاول التشييدية والاشغال المعيبة. بناءا على ما جأت به الدراسة، يوصى باتاحة الدعم المالى والتقنى قبل تحقيق التنفيذ الفعلى فى صناعتنا الماليزية.

APPROVAL PAGE

I certify that I have supervised and read this study and that in my opinion, it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a thesis for the degree of Master of Science Built Environment.

…….....
Maisarah Ali
Supervisor

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a thesis for the degree of Master of Science Built Environment.

…….....
Shamzani Affendy Mohd Din
Examiner

This dissertation was submitted to the Department of Architecture and is accepted as a fulfilment of the requirement for degree of Master of Science Built Environment.

…….....
Muhammad Abu Eusuf
Head, Department of Building
Technology Engineering

This dissertation was submitted to the Kulliyyah of Architecture and Environmental Design and is accepted as a fulfilment of the requirement for degree of Master of Science Built Environment.

…….....
Khairuddin Abdul Rashid
Dean, Kulliyyah of Architecture
and Environmental Design

DECLARATION

I hereby declare that this dissertation is the result of my own investigations, except where otherwise stated. I also declare that it has not been previously or concurrently submitted as a whole for any other degrees at IIUM or other institutions.

Julia Mohd Nor

Signature…… Date ……

INTERNATIONAL ISLAMIC UNIVERSITY MALAYSIA

DECLARATION OF COPYRIGHT AND AFFIRMATION OF FAIR USE OF UNPUBLISHED RESEARCH

FEASIBILITY STUDY OF FOUR DIMENSION (4D) VIRTUAL CONSTRUCTION TOOL TO MITIGATE DELAYS DURING CONSTRUCTION

Affirmed by Julia Mohd Nor.

…… ……...

Signature Date

ACKNOWLEDGEMENTS

All praises due to Allah, for the strength He has given me to complete this research and produce this thesis. I started off my journey as a student again after leaving campus for almost 20 years and here I am feeling great relief and *syukur* for every moment that I've gone through, as I was tested by Him.

I would like to dedicate my deepest gratitude to the special people who have one way or another supported me up to this very moment and to some extent responsible for the thesis that I have come up with.

First and foremost, Professor Dr. Khairuddin Abdul Rashid, my supposed-to-be main supervisor when I first came to Kulliyyah of Architecture and Environmental Design (KAED). Thank you, Sir. Thank you for the guidance, support and not to mention the motivation and your concern in educating me even within that very short of time.

My friend and also my Co-Supervisor, Asst. Professor Dr. Puteri Shireen Jahn Kassim who had first invited me to join her at KAED. Thank you so much for the trust and support that you have given me.

Special thanks to Assoc. Professor Ir. Dr. Maisarah Ali who has given me the strength to strive and move on especially during my injury. Thank you for the trust, guidance, motivation and support, and I'm grateful to have you as my Supervisor.

My deepest thanks to ALL the academic and administration staff of KAED for the support and kindness up to the very last minute the thesis is produced, especially to Sr. Aida, our PG Officer and to Sr. Aizah during the earlier stage.

My family, my mum and dad who have been my backbone all these years. Thank you so very much for your love, support and prayers. Nothing can ever describe how much I owe both of you for who and what I have become today.

Last but not least, this research would not have been successful without these individuals who have generously assisted me throughout my data collection period especially, Dato' Ir. Mohd Nor Ismail, Development Director of JPPHB, University of Malaya; Professor Ar. Dr. Hamzah from Faculty of Built Environment, University of Malaya, Ir. Nazari and Ir. Halimaton of JKR PROKOM, principals of consulting firms and contractors, and also friends who have given me the support and trust in one way or another. THANK YOU SO VERY MUCH.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

2D	2-dimensional
3D	3-dimensional
3D CAD	3-dimensional Computer Aided Design
4D	4-dimensional
4D CAD	4-dimensional Computer Aided Design
AEC	Architecture, Engineering and Construction
CE	Concurrent Engineering
CPM	Critical Path Method
GDP	Gross Domestic Product
PWD	Public Works Department
VR	Virtual Reality

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND TO RESEARCH

1.1.1 Malaysian Construction Industry

During the 7th Malaysia Construction Sector Review and Outlook Seminar on the 3rd August 2010 held at Putra World Trade Centre, Kuala Lumpur, it was highlighted by the Minister of Works Malaysia, the "Yang Berhormat" Dato' Shaziman Abu Mansor that the Construction Sector registered a strong growth of 5.8% in 2009, followed by a subsequent 8.5% for the first quarter of 2010 as against the overall Gross Domestic Product (GDP) growth of 10.1% during that first quarter of the year.

In terms of value of projects, there was already a substantial improvement in the performance of the 9th Malaysian Plan and it is expected that the Construction Sector will grow at 3.7% per annum as compared to 6% per annum GDP growth for the country under the 10th Malaysian Plan which covers the period from 2011 to 2015. In supporting the Plan, the Ministry of Works has identified five strategic initiatives for effective implementation of construction projects and enhancement of the construction industry. They are:

i. The revision and establishment of construction industry related acts;
ii. The enhancement of processes and technologies;
iii. Leveraging on information and communication technology (ICT);
iv. Strengthening enforcement and project monitoring; and lastly
v. Capacity enhancement of professionals, contractors and workforce.

It was also emphasized that towards achieving a High Income Economy, there is a need to enhance the environment under which construction stakeholders operate and in enhancing significant increase in productivity, there is a need for sharing of information based on an integrated ICT system and database not only within the agencies in the Ministry of Works but also with other agencies which are related to the construction industry.

This sharing of information and integration of various IT based systems, although still in the inception plan, is expected to promote a more effective project monitoring system for the 10th Malaysian Plan projects that are managed by the Ministry. As the main implementing agency of construction projects for the 10th Malaysian Plan, the Ministry is aggressively targeting at zero-delay in the implementation of projects where it also intends to revisit and fine tune the delivery system, ensure better enforcement capabilities and to have more effective project monitoring mechanisms in place.

Among his concluding remarks, the Minister of Works Malaysia has also emphasized that in achieving this aspiration, the Project Supervision Team has to be led by certified project manager in ensuring that projects are duly managed and closely monitored to ensure success.

1.1.2 Current Practices in Malaysia

By definition, construction means the act or process of constructing, and management means the act of handling and controlling something successfully. However, in the fields of architecture and engineering, construction is a feat of multitasking process that consists of the building or assembling of infrastructure managed by a team of technical professionals.

In relation to the current practices of project control in our Malaysian construction industry, surprising but true, the construction projects in Malaysia have all been implemented, monitored and controlled towards completion using printouts of 2D drawings, forms of construction scheduling and also based on intuitive responses, judgments and experience of the experts involved in a project team.

Typically, a project team consists of clients represented by owners and/ or developers, Local Authorities as the regulatory bodies, contractors and design consultants comprising of professional Architects, Civil/ Structural Engineers, Mechanical Engineers, Electrical Engineers and Quantity Surveyors. As a team, project team members are expected to bring their own disciplinary or individual views to the decision making process to reduce anticipated delays and this collaborative decision making is required within a concurrent engineering framework to ensure project success (Gunasekaran, A. and Love, P.E.D., 1998).

In the context of the construction industry, Anumba, C.J. et al. (2002) defines Concurrent Engineering (CE) as an attempt to optimize the design of the project and its construction process to achieve reduced lead times, and improved quality and cost by the integration of design, fabrication, construction and erection activities and by maximizing concurrency and collaboration in working practices.

Several framework proposals for the adoption of the principles of CE for use in the construction industry have been made among which, the framework for the traditional approach indicates that based on the client brief, architectural design is produced by architect and is passed on to structural engineer to complete the structural design, and later to quantity surveyor to produce the costing and bill of quantities. This goes on until the project is then passed on to the contractor who takes

responsibility for the construction of the facility upon award. This traditional "over the wall" framework is illustrated in Figure 1.1 presented below.

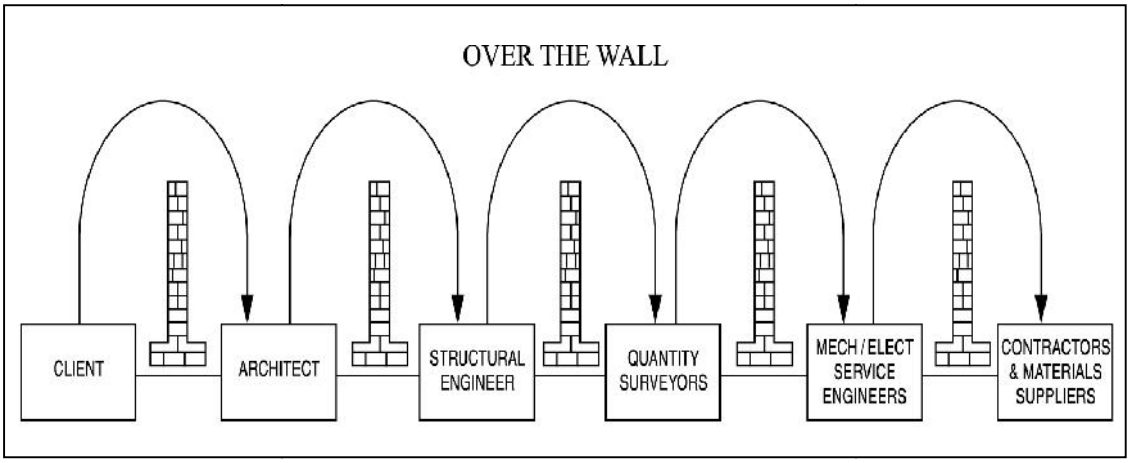


Figure 1.1: The "over the wall" Approach
(Source: Evboumwam and Anumba, 1998; Prasad, 1997)

1.1.3 Project Control in Malaysia

As mentioned earlier and enhanced by Chau, K.W. et al. (2004), clients' requirements are still being presented in terms of paper-based working drawings i.e. the 2D drawings and a project schedule that links different construction activities on the basis of these working drawings formulated by the contractors. In current practice, site progress is being monitored as and when on a day-to-day basis according to these 2D drawings and the intended project schedule, where physical activities are being controlled and decided upon during periodic site meetings and ad-hoc sessions.

1.1.3.1 2D Drawings

2D drawings are displays of site-planning information that are being transformed in a 2D environment via AutoCAD produced on papers or printouts for construction purposes. AutoCAD is a CAD (Computer Aided Design or Computer Aided Drafting)

software application for 2D and 3D design and drafting, which was first released in December 1982. It was developed and sold by Autodesk, Inc. and was one of the first CAD programs to run on personal computers, notably the IBM PC (http://en.wikipedia.org/wiki/AutoCAD).

This site-planning information includes the overall site layout, conceptual and detailed design drawings as well as schedules of structures involved in a project. In current practice, the physical works on site will be delivered as per designed and produced on these 2D drawings and checked upon by the project team against the project schedule. At this point, construction practitioners need to conceptualize the construction sequence in their minds by associating the components in 2D drawings together with the activities in the schedule.

At norm, design is bound to be altered as the work progresses on site (due to change in decision by the end-users or unforeseen site constraints); following which these 2D design drawings and other affected detailed drawings are revised and re-issued to all parties accordingly. A sample illustration of 2D drawing is presented in Figure 1.2 shown below.

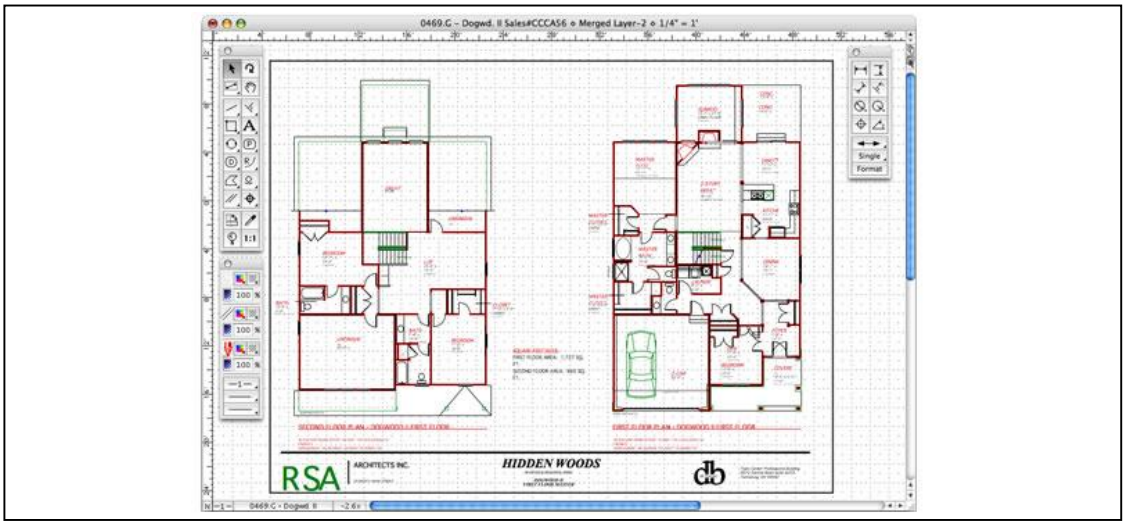


Figure 1.2: Sample 2D AutoCAD Drawing (Source: http://www.google.com.my/)

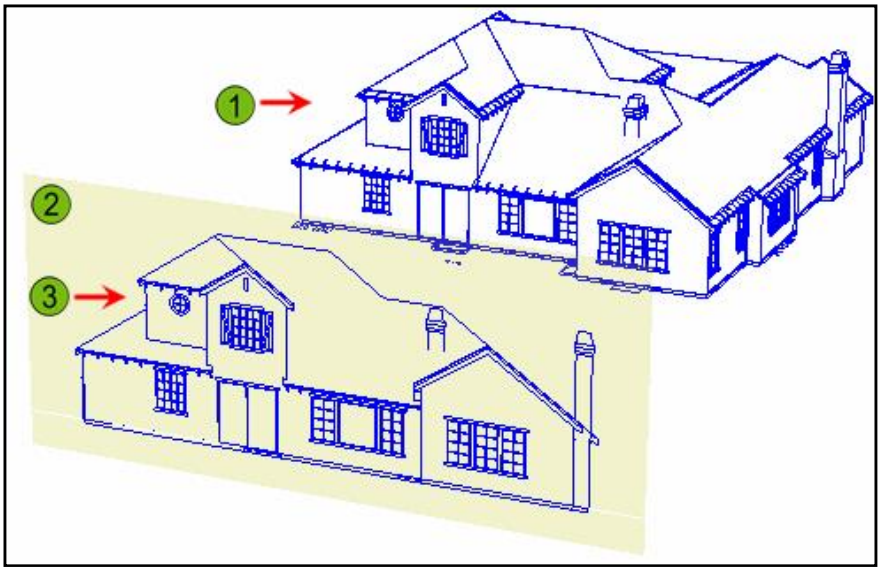
Additionally, 2D drawings present many advantages since they are industry standards (DWG, DXF formats) and can easily be converted into other standard 2D formats such as PDF or JPG.

1.1.3.2 3D Models

3D CAD models are very complex and the storage formats are usually proprietary to a specific software product. In architecture domain, 3D CAD software is becoming the design tool of choice catering to the architecture, engineering and construction (AEC) industry, especially AutoCAD, Revit and Microstation. They are increasingly used across all phases of building project life cycle management and have become essential in most design professions and branches that deal with the built world – past, present or future (http://en.wikipedia.org/wiki/3D_modelling).

3D models depict the geometry and various aspects of physical objects, can be shaded and rendered to view as original building, and are dynamically visualized with computer graphics, thereby facilitate better communication between various parties involved in the project and the future owners. In relation to the current scenario of Malaysian construction industry, this technology is highly appreciated in offering impressive 3D views to clients on the proposed building to be built during planning stage and also enables construction practitioners to '*walk-through'* the model of the intended building, giving due satisfaction on what to be expected should it be accomplished.

The following illustration in Figure 1.3 shows how a 3D model is projected onto a viewing plane, resulting in a 2D elevation which is better suited for construction documentation whilst the 3D perspective image does a better job in conveying the overall design.



1 3D model
2 Plane representing 2D view
3 Resulting flattened view for the elevation

Figure 1.3: Illustration of Sample 3D Model (http://en.wikipedia.org/wiki/3D Model)

1.1.3.3 Microsoft Project (MS Project)

The Microsoft Project (MS Project) is a project planning and scheduling software produced by Microsoft as a tool to assist construction practitioners especially the project managers to plan, monitor, control and track project status, activities, detailed costing and resource allocations at any point of time during its implementation period in order to achieve the organization's strategic and business objectives (http://en.wikipedia.org/wiki/Microsoft_Project).

The project schedule produced by this software is commonly known as the *"Work Programme"* by practitioners, which at present, is the main scheduling tool used for project monitoring by government agencies eg. the Public Works Department (PWD) nationwide and is also observed to be the most commonly used tool besides Gantt Chart among other construction practitioners in the industry.

A simple sample of this MS Project outlook on a project model is displayed in Figure 1.4 below.

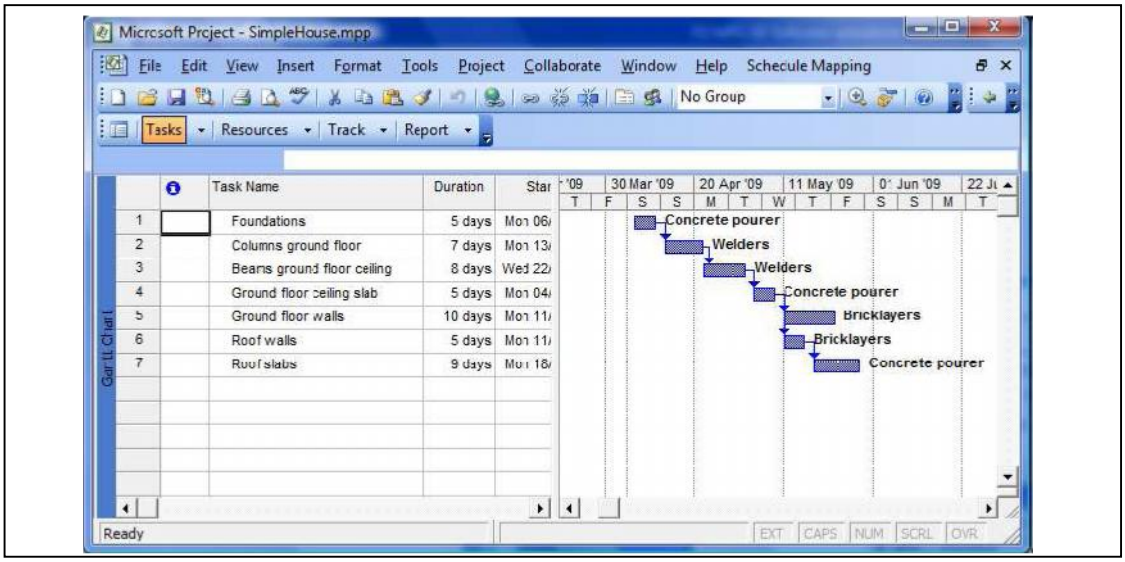


Figure 1.4: Sample Microsoft Project (MS Project) Outlook
(Source: nDCCIR – Operation Manual Revision 1.4, 5-05-2009, Dawood)

1.1.4 Problems Faced by Malaysian Construction Industry

In current practice, the existing technology and processes employed to deliver those practices are proven inadequate in addressing the increased complexity of projects and incessant market demand for shorter construction time-scales (Allen, C. and Smallwood, J., 2008).

As projects get more and more complex, the issue of constructability becomes more important. Constructability is a project management technique for reviewing construction processes from start to finish during pre-construction phase. In the traditional contracting system, most design drawings and specifications produced tend to be performance oriented, specifying an end result and materials, while leaving the means and methods for constructing the work to the contractor; which by nature,