STUDY ON PERCEPTION OF BIM EFFECTIVENESS WITHIN CONSTRUCTION INDUSTRY

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I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

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ABSTRAK

Pemodelan Maklumat Bangunan (BIM) merupakan salah satu teknologi baru yang diperkenalkan kepada pemain berkaitan pembinaan sebagai alat berkomunikasi utama dalam projek pembinaan. BIM telah banyak digunakan di banyak negara. Di Malaysia, idea untuk melaksanakan BIM diperkenalkan oleh Pengarah Jabatan Kerja Raya (PWD) pada tahun 2007. BIM telah mula mengubah bagaimana pereka bekerjasama dengan perunding dan pembina, dan juga mempunyai keupayaan untuk membimbing industri ke arah pengeluaran bangunan memenuhi matlamat pembangunan mampan dan operasi kemudahan modal baru atau kemudahan yang dimodelkan semula (moden). Kerajaan telah mula menggalakkan pemain berkaitan pembinaan Malaysia untuk beralih dari amalan semasa ke pelaksanaan BIM. Pelaksanaan BIM dalam industri pembinaan tanpa ragu-ragu telah memberikan beberapa kelebihan ke arah pihak-pihak pembinaan di seluruh dunia. Keberkesanannya telah dibuktikan oleh beberapa pihak di seluruh dunia. Walau bagaimanapun, masih belum pasti di mana aspek semasa projek pembinaan BIM boleh dilihat sebagai yang paling berkesan. Kajian ini bertujuan untuk mengenal pasti aspek yang paling penting semasa projek pembinaan dimana BIM boleh dikatakan sebagai yang paling berkesan. Maklumat ini penting bagi pemain pembinaan untuk menarik mereka ke arah pelaksanaan BIM di Malaysia. Untuk mencapai matlamat kajian ini, semakan kajian semula secara intensif dan temu duga dilakukan di samping soal selidik yang digunakan untuk responden. RII digunakan untuk menganalisis data. Dari kajian ini, kami mendapati bahawa BIM masih belum digunakan secara meluas di Malaysia mengikut data yang diterima daripada tinjauan soal selidik dan kajian literatur yang dijalankan. Selain daripada itu, dari data kaji selidik juga, kita dapat menyimpulkan bahawa faktor yang dianggap sebagai yang paling penting di antara faktor-faktor yang dipilih adalah keupayaan BIM untuk melakukan pemeriksaan pertembungan bagi keseluruhan model reka bentuk yang telah dimuktamadkan. Data tinjauan juga menunjukkan bahawa aspek yang mana BIM boleh dikatakan sebagai yang paling berkesan ialah semasa bantuan reka bentuk dan pembinaan. Kesimpulannya, kajian ini berjaya mencapai matlamat yang dicadangkan. Hasil daripada kajian ini tidak jauh dari hasil yang dijangkakan yang pelaksanaan BIM di Malaysia masih rendah dan ia adalah yang paling berkesan semasa aspek bantuan reka bentuk dan pembinaan. Mudah-mudahan, semua maklumat yang disediakan di dalam tesis ini dapat memberi semangat kepada para pemain pembinaan untuk menggunakan BIM dalam projek masa depan mereka.

ABSTRACT

Building Information Modelling (BIM) is one of the newer technologies introduced to the construction related players as the principal communicating tools in the construction project. BIM has been widely used in many countries. In Malaysia, the idea to implement BIM was introduced by the Director of Public Works Department (PWD) in 2007. BIM has already begun changing how designers collaborate with consultants and builders, and it also has the capability to guide the industry towards the production of buildings meeting sustainable development goals and operation of a new capital facility or a recapitalized (modernized) facility. The Government has started to encourage Malaysian construction related players to shift from current practices to BIM implementation. BIM implementation in construction industry without a doubt had provided several advantages towards the construction parties around the world. Its effectiveness has been proven by several parties across the globe. However, it is still uncertain in which aspect during construction projects does BIM can be viewed as the most effective. This study aims to identify the most crucial aspect during construction project where BIM can be said as being the most effective. These information is crucial to construction players in order to attract them towards BIM implementation in Malaysia. To achieve the aim of the study, intensive review literature review and interview were conducted beside deployed questionnaires to the respondents. RII were used to analyze the data. From the study, we found that BIM was still not yet widely used in Malaysia according to the data received from conducted questionnaire and literature reviews. Other than that, from the survey data also, we can concluded that the factor which deemed as the most important among the factors chosen was the BIM capability to do clash checking for the whole finalized design model. The survey data also indicated that the aspect where BIM can be said as being the most effective was during design assistance and constructability. In conclusion, this study managed to achieve the proposed objective. The outcome from this study does not stray far away from the expected outcome which is BIM implementation in Malaysia is still low and it is the most effective during aspect of design assistance and constructability. Hopefully, all the information provided inside this thesis can provide encouragement towards construction players to use BIM in their future projects.

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LIST OF ABBREVIATIONS

BIM	Building Information Modelling
PWD	Public Works Department
CAD	Computer-Aided Design
CITP	Construction Industry Transformation Program
CIDB	Construction Industry Development Board Malaysia
AEC	Architecture, Engineering and Construction
RII)	Relative Important Index
CRC	Construction Research Congress
2D	Two-dimensional
3D	Three-dimensional
4D	Four-dimensional
5D	Five-dimensional
USA	United States of America
UK	United Kingdom
ROI	Return on Investment
MEP	Mechanical, Electrical and Plumbing
IPD	Integrated Project Delivery
BAS	Building Automation Systems
CNC	Computer Numerical Control
CPM	Critical Path Method
MEP/FP	Mechanical, Electrical, Plumbing, and Fire Protection
VDC	Virtual Design and Construction
PxP	Project Execution Plan
LOD	Level of Development
HDR	High Dynamic Range
CAM	Computer-Aided Manufacturing
HVAC	Heating, Ventilation, and Air Conditioning
RFID	Radio Frequency Identification
ICT	Information Communication and Technology
PAS 1192-2	Specification for information management for the capital/delivery phase of construction projects using building information modelling
BS 1192	Collaborative Production of Architectural, Engineering and Construction Information - Code of Practice
CDE	Cardholder Data Environment

WIP	Work-In-Progress
EPC	Engineering, Procurement and Construction
NIST	National Institute of Standards and Technology
VBE	Virtual Building Environments
RFA	Request for Application

CHAPTER 1

INTRODUCTION

1.1 Introduction

Building Information Modelling (BIM) is one of the newer technologies introduced to the construction related players as the principal communicating tools in the construction project. BIM has been widely used in many countries such as United Kingdom, United States, Australia, Singapore and etc. Many construction players have started to realize the significant benefit offered by BIM and working towards BIM implementation. In Malaysia, the idea to implement BIM was introduced by the Director of Public Works Department (PWD) in 2007. In 2010, Malaysian Government has announced that the National Cancer Institute, Sepang is the first infrastructure construction project adopting BIM in Malaysia.

Building Information Modelling (BIM) is the development and use of a multi-faceted computer software data model to not only document a building design, but to simulate the construction. BIM consists of information representing the entire building and the complete set of design documents stored in an integrated database. All the information is parametric and thereby interconnected. Any changes to an object within the model automatically affect the related assemblies and constructions, because the model contains the necessary relational information. This is quite unlike the 2D building representation of conventional CAD-based drawings. For these reasons, BIM has already begun changing how designers collaborate with consultants and builders, and it also has the capability to guide the industry towards the production of buildings meeting sustainable development goals and operation of a new capital facility or a recapitalized (modernized) facility. The resulting Building Information Model is a data-rich, object-based, intelligent and parametric digital representation of the facility, from which views

appropriate to various users' needs can be extracted and analysed to generate feedback and improvement of the facility design.

1.2 Background of Problems

As we know, Building Information Modelling (BIM) implementation has been introduced to construction industry in Malaysia a few years ago. BIM has been included and become part of national agenda under the Construction Industry Transformation Program (CITP). CITP is a five-year program (2016-2020) developed by Construction Industry Development Board Malaysia (CIDB) and was launched by the Prime Minister in September 2015 with the intention to guide, refocus the strategic position and plot the future direction of Malaysian construction industry. Therefore, the Government has started to encourage Malaysian construction related players to shift from current practices to BIM implementation.

BIM implementation in construction industry without a doubt had provide several advantages towards the construction parties around the world. Its effectiveness has been proven by several parties across the globe. However, it is still uncertain in which aspect during construction projects does BIM can be viewed as the most effective. This matter is crucial to construction players in deciding whether they should implement BIM in their projects. In fact, most of them still unclear about in which aspect BIM can actually provide benefits to their projects. Due to their lack of understanding on this matter, they became uncertain about changing their common practices into BIM which in their views, considered as a risky move. They are unsure whether they could actually gain any benefits by doing so. Misunderstanding or lack of knowledge on this matter is clearly one of the reasons why BIM are not widely accepted by construction players in Malaysia. Therefore, a clear guidance regarding this matter need to be provided on how BIM can actually being effective in construction project.

1.3 Problem Statement

BIM implementation in construction industry without a doubt had provided several advantages towards the construction parties around the world. Its effectiveness has been proven by several parties across the globe. However, it is still uncertain in which aspect during construction projects does BIM can be viewed as the most effective. This, due to their lack of understanding on this matter, they became uncertain about changing their common practices into BIM which in their views, considered as a risky move. They are unsure whether they could actually gain any benefits by doing so. Therefore, this study will analyse the most crucial aspect where BIM can be said being as the most effective.

1.4 Importance of Study

The adoption and use of Building Information Modelling (BIM) in the whole life process of designing, creating and operating buildings, assets and infrastructure projects is a worldwide growing trend. The research findings presented here are aimed to clearly state on how BIM can become effective during the construction project. The information are obtained from construction players or any related parties which happen to have experience with BIM. The research findings are intended to be used as a reference by construction players while deciding whether or not they should use BIM in their projects. By providing clear understanding on how BIM can actually benefits them, BIM implementation among construction players in Malaysia can be increased significantly.

BIM are viewed as a superior method compared to conventional method. BIM and other digital trends such as big data and sensors have potential wide-reaching implications for many industries around the world. In 2009, Malaysia was first introduced to the term BIM during the 2-day Infrastructure & Construction Asia's Building Information Modelling & Sustainable Architecture Conference. At the conference, Y. Bhg Dato' Seri Ir. Dr. Judin bin Abdul Karim, then as the Director General of Public Work Department (PWD), urged the industry to embrace technology in their deliverables.

The Malaysian government then announced its adoption of BIM in 2010 with the National Cancer Institute in Sepang being the first infrastructure construction project. Currently, both the government and the private sector is slowly adopting BIM in the projects. Several BIM platforms currently available in the market includes Revit, Bentley

REFERENCES

[1] Nurshuhada Zainon, Faizul Azli Mohd-Rahim, Hafez Salleh. “The Rise Of BIM in Malaysia And Its Impact Towards Quantity Surveying Practices”. p.p 2-6, Kuala Lumpur, 2016

[2] Kereshmeh Afsari. “Building Information Modeling in Concept Design Stage”. p.p 12-50, Indiana, 2012

[3] Małgorzata Gołaszewska, Marek Salamak. “Challenges in takeoffs and cost estimating in the bim technology, based on the example of a road bridge model”. p.p 73-78, Czech Republic, 2017

[4] Su-Ling Fan, Miroslaw J. Skibniewski, and Tsung Wei Hung. “Effects of Building Information Modeling During Construction”. p.p158-165, Taiwan, , 2014

[5] Ju Hyung Kim, Jaejun Kim. “Collaborative Process to Facilitate BIM-based Clash Detection Tasks for Enhancing Constructability”. p.p 158-166, Seoul, 2012

[6] Russell Tamblyn, Timothy A. Verwey, Humayun Qureshi, “BIM coordination and integration”, Washinton, 2018. https://www.csemag.com/articles/bim-coordination-and-integration/

[7] M M Tahir et al., “Application of building information model (BIM in Malaysian construction industry”. p.p 2-4, Kuala Lumpur,2009

[8] Anderson O. Akponeware, Zulfikar A. Adamu, “Clash Detection or Clash Avoidance? An Investigation into Coordination Problems in 3D BIM”. p.p 3-9, United Kingdom, 2017

[9] Birx, G. W. “Getting started with Building Information Modelling”. The American Institute of Architects - Best Practices, 2006. http://www.aia.org/bestpractices_index.

[10] Campbell, D. A. Building information modelling: the Web3D application for AEC. In Proceedings of the Twelfth international Conference on 3D Web Technology Perugia, Italy, 2007.

[11] Eastman, C.; Teicholz, P.; Sacks, R.; Liston, K. “BIM Handbook**.** A guide to Building Information Modelling for owners, managers, designers, engineers and contractors”. John Wiley and Sons, 2008.

[12] Kymmel, W. “Building Information Modeling. Planning and managing construction project with 4D and simulations”. p.p 53-68 McGraw-Hill 2008.

[13] Bazjanac, V. “Virtual Building Environments (VBE) - Applying Information Modeling to Buildings”. p.p 43-88 Lawrence Berkeley National Laboratory, University of California. Berkeley, CA, U.S.A., 2004.

[14] Ayres Filho, C. “Access to the integrated model of the building”. Dissertation of masters Post-Graduation in Civil Construction - Technology Sector, University Federal of Paraná. Curitiba, 2009.

[15] Ibrahim, M.; Krawczyk, R.; Schipporeit, G. “Two approaches to BIM: A Comparative Study”. eCAADe Conference. Kopenhagen, Dinamarca, 2004.

[16]Moshood Olawale Fadeyi, “The role of building information modeling (BIM) in delivering the sustainable building value”. p.p 29-33, Singapore ,2017

[17]Heiko Kirschke, “BIM (Building Information Modeling) education at Universities” p.p 1882-1893, Germany, 2016.

[18]Fallon, Mark E Palmer. General Buildings Information Handover Guide: Principles, Methodology and Case Studies. National Institute of Standards and Technology (NIST), NISTIR 7417. New Mexico, 2007

[19]Ito, A.L. “Information management in the design process of architecture: case study”. University Federal of Paraná, Curitiba, 2007

[20]Hergunsel, M.F.”Benefits of building information modeling for construction managers and BIM based scheduling,” Master Thesis, Department of Civil Engineering, Worcester Polytechnic Institute, UK. 2011

[21]Maunula, A & Riitta, Smeds & Hirvensalo, Antero. (2008). Implementation of Building Information Modeling (BIM) - A process perspective. Innovations in Networks - Proceedings of the APMS 2008 Conference, An Event of the IFIP Working Group 5.7. 379-386.

[22]Ashcraft, H.W.. (2008). Building information modeling: A framework for collaboration. Construction Lawyer. 28. 1-14.

[23]Smith, D.K. and M. Tardiff, 2009. Building Information Modeling: A Strategic Implementation Guide. John Wiley and Sons Inc., Hoboken.

[24]Baba, H.D., 2010. Building information modeling in local construction industry. M.A. Thesis, Faculty of Civil Engineering, Universiti Teknologi Malaysia, Malaysia.

[25]Azhar, S., 2008. Building Information Modeling (BIM): A new paradigm for visual interactive modeling and simulation for construction project. Proceeding of 1st International Conference on Construction in Developing Countries (ICCIDC-I), Advancing and Integrating Construction Education, Research and Practice. Karachi, Pakistan.

[26]Bentley, 2013. Seminars and Trainings on BIM. Retrieved from: http://www.bentley.com/enUS/Engineering+Architecture+Construction+Software+Resources/Bentley+Software+Events+Seminars/

[27]Morrison, C., 2010. BIM 2010: The benefit and barriers for construction contractor in the Auckland. A Report for Industry Project CONS 7819, Unitect, New Zealand.

[28]Zhigang Shen, Raja R.A. Issa, 2010. “Quantitative Evaluation Of The Bim-Assisted Construction Detailed Cost Estimates”, Florida, USA

[29]Garrett, J.H. A Machine Learning Decision Support System for Collaborative Design. Available online:http://repository.cmu.edu/cgi/viewcontent.cgi?article=1056&context=cee (accessed on 14 September 2018).

[30]Van Den Helm, P.; Böhms, M.; Van Berlo, L. IFC-based clash detection for the open-source BIMserver. Survey of known technologies used for IFC clash detection. 2009.

Availableonline:http://bimserver.org/wpcontent/uploads/sites/6/2010/11/Helm_Clashdetection.pdf (accessed on 14 October 2018).

[31]Iskdag, U., Underwood J., Aouad G., Trodd N., Investigating the Role of Building Information Models as a Part of an Integrated Data Layer: A Fire Response Management Case, “Architectural Engineering and Design Management”, Vol. 12, 2006, 124–142.

[32]Hajian, Hamid, and Burcin Becerik-Gerber. "A Research Outlook for Real-time Project Information Management by Integrating Advanced Field Data Acquisition Systems and Building Information Modeling." University of South California. 2009.

[33]Mehmet F. Hergunsel, “Benefits Of Building Information Modeling For Construction Managers And Bim Based Scheduling”, Massachusetts, 2011.

[34]Hans-Joachim Bargstädt, “Challenges of BIM for Construction Site Operations”, p.p 56-57, Germany, 2015

[35]Lowe, R. H., and Muncey, J. M. (2009), “ConsensusDOCS 301 BIM Addendum”, Construction Lawyer, Volume 29 (1), p.p 17.

[36]Poerschke, Ute & Holland, Robert & Messner, John & Pihlak, Madis. (2010). BIM collaboration across six disciplines.

[37]Khemlani, L.; Papamichael, K.; and Harfmann, A. (November 02, 2006). “The Potential of Digital Building Modeling” [WWW document]. URL http://www.aia.org/SiteObjects/files/potentialofdigital.pdf

[38]Meadati, Pavan & Ap, Leed & Irizary, Javier. “BIM – A Knowledge Repository”, Georgia, 2014.

[39]Nuzul Azam Haron, Aizul Harun, R.P.Z.A. Raja Soh, “Implementation of building information modelling (Bim) in malaysia: A review”, Selangor, 2017