FACTORS INFLUENCING ADOPTION OF BUILDING INFORMATION MODELING BY MALAYSIAN QUANTITY SURVEYING FIRMS

BY

JULIAN BT OSMAN

A thesis submitted in fulfilment of the requirement for the degree of Doctor of Philosophy in Built Environment

Kulliyyah of Architecture and Environmental Design
International Islamic University Malaysia

JUNE 2019

ABSTRACT

Building Information Modeling (BIM) is making its way into more professional firms/ organisations within the architecture, engineering and construction (AEC) industry. However, quantity surveying (QS) firms/ organisations have been singled out to be slow adopters. Despite its reported benefits, the uptake by QS firms/ organisations has still been found to be considerably low. Review of the extant literature on BIM adoption has shown that limited studies were undertaken to determine the factors that influence organizational adoption of BIM, with specific reference to QS firms/ organisations. Thus, the aim of this study was to determine the significant factors that influence the intention to adopt BIM by Malaysian QS firms/ organisations. Two main research objectives were formulated which are i) To ascertain the level of awareness and understanding of BIM concepts among QSs, and ii) To determine factors within the context of Technology, Organisation and Environment and their influence on the adoption of BIM by QS firms. By synthesising Diffusion of Innovation (DOI) theory, Institutional Theory and Technology-Organisation-Environment framework, a conceptual model was developed. The technology context was represented by four independent variables namely (i) relative advantage, (ii) complexity, (iii) interoperability and (iv) cost. Within the organisational context, five independent variables namely (i) top management support, (ii) technology readiness, (iii) financial resources, (iv) training and (v) perceived risks were identified. Moreover, under the environmental context, three independent variables namely were identified: (i) external pressure, (ii) external support and (iii) government support. All these contexts were then used to predict the intention to adopt BIM within QS firms/ organsations in Malaysia. This study utilized questionnaire survey as the primary data collection method which was sent to 315 registered Malaysian QS firms/ organisations. Apart from descriptive statistics, structural equation modelling was used as the data analysis method. The research findings indicated the validity of a second-order factor of all the hypothesized contexts. Technology contexts has been found to be a second-order factor with four dimensions namely relative advantage, complexity, interoperability and cost. In addition, the organisational context has also been found to be a second-order factor with five dimensions namely top management support, technology readiness, financial resources, training and perceived risks. Lastly, the environmental context has also been found to be a second-order factor with three dimensions namely external pressure, external support and government support. Furthermore, this study has also asserted that the technological context to be the most influential context on the intention to adopt BIM by Malaysian QS firms. This is followed by the organizational context. However, the environmental context has been found to have no significant influence on the intention to adopt BIM by Malaysian QS firms. Thus, this study suggests that management of QS firms allocate sufficient resources to tackle the technology context and organistional context in order to increase the chances of adopting BIM.

خلاصة البحث

العمارة والهندسة والبناء، ولكن؛ تبدو الشركات والمنظمات المتخصصة بمسح الكميات بطيئة في تبنّيها هذه النمذجة رغم فوائدها المعروفة، فقد أظهرت مراجعة الدراسات أن قليلاً منها يعنى بدراسة العوامل التي تؤثر في اعتمادها، ومن ثم؛ يهدف البحث إلى تحديد العوامل التي تؤثر في نية اعتماد نمذجة معلومات البناء لدى الشركات والمنظمات المتخصصة بمسح الكميات في ماليزيا؛ وذلك لغايتين؛ إحداهما التأكد من مستوى الوعي بمفاهيم نمذجة معلومات البناء لدى تلك الشركات والمنظمات، والثانية تحديد العوامل التقنية والتنظيمية والبيئية المؤثرة في اعتمادها، وقد طوَّرت الباحثة إطارًا نظريًّا يعتمد على توليفة من: نظرية انتشار الابتكار، والنظرية المؤسسية، والإطار النظري للبيئة التقنية للمنظمات، ومُثِّل السياق التقني في هذا البحث في أربعة متغيرات مستقلة هي: الميزة النسبية، والتعقيد، وقابلية التشغيل البيني، والتكلفة؛ ومُثِّل السياق التنظيمي في خمسة متغيرات مستقلة هي: دعم الإدارة العليا، والاستعداد التقني، والموارد المالية، والتدريب، والمخاطر المتصورة؛ بينما مُثِّل السياق البيئي في ثلاثة متغيرات مستقلة هي: الضغط الخارجي، والدعم الخارجي، والدعم الحكومي، واستُخدمت هذه السياقات للتنبؤ بنية تبني نمذجة معلومات البناء لدى الشركات والمنظمات المتخصصة بمسح الكميات في ماليزيا، وتوسَّلت الباحثة الاستبانة لجمع البيانات الأولية التي أُرسلت إلى 315 شركة ومنظمة في ماليزيا، إضافة إلى نمذجة المعادلات الهيكلية لتحليل البيانات، وأوضحت النتائج صحة عامل من الدرجة الثانية لجميع السياقات المفترضة، وبيَّنت أن السياق التقني عامل من الدرجة الثانية ذو أبعاد أربعة هي: الميزة النسبية، والتعقيد، وقابلية التشغيل البيني، والتكلفة؛ وأن السياق التنظيمي عامل من الدرجة الثانية ذو أبعاد خمسة هي: دعم الإدارة العليا، والاستعداد للتقنية، والموارد المالية، والتدريب، والمخاطر المتصورة؛ وأن السياق البيئي أيضًا عامل من الدرجة الثانية ذو أبعاد ثلاثة هي: الضغط الخارجي، والدعم الخارجي، والدعم الحكومي، وأكَّد البحث كذلك أن السياق التقني هو الأكثر تأثيرًا في نية اعتماد نمذجة معلومات البناء لدى الشركات والمنظمات المتخصصة بمسح الكميات في

ماليزيا، يليه السياق التنظيمي، أما السياق البيئي فليس له تأثير كبير، وعليه؛ يشير البحث إلى أنه ينبغي لإدارات الشركات والمنظمات المتخصصة بمسح الكميات في ماليزيا أن تخصص موارد كافية لمعالجة السياقين التقني والتنظيمي؛ لزيادة فرص اعتماد نمذجة معلومات البناء.

APPROVAL PAGE

The thesis of Julian Bt Osman has been approved by the following:

____
Sharifah Mazlina Syed Khuzzan
Supervisor

____
Abdul Razak Sapian
Co-supervisor

____
Abdul Rahman Ahlan
Internal Examiner

____
Kherun Nita Ali
External Examiner

____
Hafez Salleh
External Examiner

____
Saim Kayadibi
Chairman

DECLARATION

I hereby declare that this thesis 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.

Julian Bt Osman

Signature .... Date ....

INTERNATIONAL ISLAMIC UNIVERSITY MALAYSIA

DECLARATION OF COPYRIGHT AND AFFIRMATION OF FAIR USE OF UNPUBLISHED RESEARCH

FACTORS INFLUENCING ADOPTION OF BUILDING INFORMATION MODELING BY MALAYSIAN QUANTITY SURVEYING FIRMS

I declare that the copyright holders of this thesis are jointly owned by the student and IIUM.

No part of this unpublished research may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording or otherwise without prior written permission of the copyright holder except as provided below

1. Any material contained in or derived from this unpublished research may only be used by others in their writing with due acknowledgement.

2. IIUM or its library will have the right to make and transmit copies (print or electronic) for institutional and academic purposes.

3. The IIUM library will have the right to make, store in a retrieved system and supply copies of this unpublished research if requested by other universities and research libraries.

By signing this form, I acknowledged that I have read and understand the IIUM Intellectual Property Right and Commercialization policy.

Affirmed by Julian Bt Osman

……..…………………….. Signature

……………………….. Date

This thesis is dedicated to my late Mother, Kamsiah bt Ali…

ACKNOWLEDGEMENTS

In the name of Allah, who is the Most Gracious.

First and foremost, thank you Allah the Most Merciful for the strength You have given me to endure this journey.

I would like to express my heartfelt gratitude to my supervisor, Dr. Sharifah Mazlina Syed Khuzzan for her kindness and understanding and to my co-supervisor, Prof. Ar. Dr Abdul Razak Sapian for his insights and advices. My indebtedness to them for believing in me and supporting me for whatever I did (or didn't do, for that matter). Thank you to you both from the bottom of my heart.

I wish to thank the Ministry of Higher Education (MOHE) Malaysia and International Islamic University Malaysia (IIUM) for the financial assistance and kind considerations.

I also would like to thank all the respondents of this research without whom this research would not have been materialised. Thank you for their time and effort.

Special thanks to my supportive husband, Amir Hamzah, who voluntarily takes over preparing the meals so as to give me some 'me-time' towards the final stage…to my girls, Humaira, Ulya and Muya, who always have kind words of encouragement…to my boys, Muhaimin and Mulhim, who lavished me with constant prayers and to my loving sister, Fatimah, for her everlasting love and generosity. This journey would have been unbearable if without your love, support and sacrifices.

Last but not least, I would like to say goodbye to the duo, Mrs Hypertension and Miss Acute Migraine, that have been my closest constant companion over the last two years of my study period... may we never cross path again!

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

4GLs	Fourth Generation Programming Language
AHP	Analytic hierarchy procession
BCIS	Building Cost Information Service
BIM	Building Information Modelling
CAD	Computer-aided Design
CAM	Computer-aided Manufacturing
CASE	Computer-aided Software Engineering
CFA	Confirmatory Factor Analysis
CIDB	Construction Industry Development Board
CITP	Construction Industry Transformation Programme
CSF	Critical success factors
DBMS	Database Management system
EDI	Electronic Data Interface
EDP	Electronic Data Processing
EIS	Executive Information System
ERP	Enterprise resource planning
FA	Factorial Analysis
GDSS	Group Decision Support System
IFC	Industry Foundation Class
IOS	Interorganisational systems
IS	Information System
ISDN	Integrated Services Digital Network
MCDM	Multi-criteria decision making
MRP	Material Requirements Planning
NBS-UK	National Building Specification - United Kingdom
OOPS	Object-oriented Processing System
OSS	Open source software
QS	Quantity surveyor (quantity surveying?)
SEM	Structural equation modelling

CHAPTER ONE

INTRODUCTION

1.1 INTRODUCTION

This chapter discusses the background of the thesis and defines the problem of the research. Following this, the research questions are presented and the research aim and objectives are established. The chapter also introduces the significance of the research and concludes with an outline of the structure for the thesis.

1.2 RESEARCH BACKGROUND

Building Information Modelling (BIM) is a digital representation of the physical and functional characteristics of a facility (USGSA, 2007). The multidimensionality in BIM is achieved by creating digital models for different parts and assemblies which incorporate additional information (Eastman, Teicholz, Sacks & Liston, 2011). BIM is acknowledged within the industry to have the potential to improve productivity and quality which ail the industry for long.

A considerable amount of literature has been published on the enormous potentials of BIM to positively affect the construction industry processes. Some authors claimed that BIM permits designers to enhance their design not only by providing the possibility of designing more complex structures (eg Yukun & Wei, 2008), but also allowing technical analysis of building performance to be done during design stage (Eastman et al, 2011; Azhar, Brown & Farooqui, 2009; Wang, Li & Chen, 2010; Bazjanac, 2005). Thus, designers not only create intricate buildings but also sustainable buildings (Bryde, Broquetas & Volm, 2013; GhaffarianHoseini, Doan, Naismith & GhaffarianHoseini, 2017).

Apart from enhanced design, BIM is also argued to be able to produce more effective and efficient processes. BIM allows multi-dimensional manipulation of drawings thus giving better visualization of the proposed building. Estimators are more efficient when they are able to visualize and rotate designs in 3D which would allow them to see the details that conventional drawings are unable to provide. Hence, this will result more accurate estimates prepared by the estimators (Shen & Issa, 2010; Sylvester & Dietrich, 2010; Mitchell, 2012; Lee, Tsong & Khamidi, 2016; Ismail, Drogemuller, Beazley & Owen, 2016). Furthermore, BIM solution also allows for automated quantity extraction (auto-quantification) which would not only saves time but also reduce errors and inconsistencies (Hannon, 2007; Ashcraft, 2008; Olatunji, Sher & Gu 2010; Smith, 2016).

Better visualization will facilitate builders to visualise what they will be constructing. This will assist the construction management team concerned with the entire project in planning their resources (Ashcraft, 2008; Lattifi, Mohd & Rakiman, 2016). Improved constructability will save time and cost; and indirectly improve and enhance the quality of the buildings (Newton & Chileshe, 2012; Jordani, 2008; CRC for Construction Innovation, 2007; Xu, 2017). In addition, better visualisation will also mean improved quality of contract documentations (Kymmell, 2008; Ismail et al., 2016). This is due to the more understanding of the design intent of the designers to be translated into documentation.

Construction industry has been known to be slow in adopting any new technology innovation (Yang, 2007). Although there are numerous benefits involved when adopting BIM such as those described above, there are also other factors which impact negatively on the rate of uptake in the industry. A significant amount of literature has been published on the challenges of BIM adoption and implementation (eg Yan & Demian, 2008; McAdam, 2010; Craig and Robbie, 2008; McGraw Hill Construction, 2011; Liu, Issa & Olbina, 2010; CREAM, 2014; Memon, Rahman, Memon & Azman, 2014). Barriers such as cost, training, interoperability, and changes in the overall design process are found often throughout the various literatures, and as such seem significant in setting back the adoption of BIM in the industry. Hence, a study is crucial to be conducted in order to understand the factors influencing its adoption within the industry.

1.3 RESEARCH PROBLEM

Despite reported benefits of BIM paving the way for adoption by industry players, the rate of uptake is not as encouraging as expected worldwide such as shown in developed western countries (Masterspec, 2013; McGraw Hill Construction, 2012; McGraw Hill Construction, 2010; NBS-UK, 2013), it cannot be said the same for Middle East and Asia countries (McGrawHill Construction- ME, 2011; Won, Lee & Lee, 2009; Baba, 2010; Jayasena & Weddikkara, 2012; Ismail, Chiozzi & Drogemuller, 2017). The rate of adoption of BIM in the UK has increased from 13% in 2010 to 31% in 2011 to 49% in 2012 which places BIM Maturity in UK at Level 1 (Khosrowshahi & Arayici, 2012). Moreover, BIM adoption in the USA has also increased remarkably from 28% in 2007 to 49% in 2009 to 71% in 2012. However, BIM maturity level is acknowledged to be at infant stage or Level 0 within South Korea (Won, Lee & Lee, 2009; Tsai, Mom & Hsieh, 2014), Sri Lanka (Jayasena & Weddikkara; 2013), Indonesia (Hanifah, 2016), India (Sawhney, Kapoor, Kamthan, Agarwal, Bhakre & Jain, 2014) as well as Malaysia (Baba, 2010). Jamal, Mohammad, Hashim, Mohaed & Ramli (2019) reiterate that adoption rate of BIM in Malaysia generally is still low. In China, Zhang, Wang, Chen & He (2014) informed that while they are advancing the adoption of BIM among contractors, its usage is only for basic applications such as visualization and clash detections.

Aside from differences of uptake rate between countries, there is also differences of adoption rate between industry players. Major surveys conducted reveal the primary adopters are architects, then engineers and followed by contractors (McGrawHill Construction - ME, 2011; Masterspec, 2013; McGraw Hill Construction, 2012; McGraw Hill Construction, 2010; NBS-UK, 2013). Conversely, cost consultants (quantity surveyors (QS)/estimators) lag behind their counterpart (Zhou, Perera, Udeaja & Paul, 2012). Even though quite a number of surveys were conducted on other key players, limited surveys were carried out to study the rate of adoption among cost consultants. In 2011, BCIS undertook a major survey among surveyors in UK to capture the rate of adoption and their perception on BIM. The study demonstrated only 10% rate of usage and only 4% use it regularly. Likewise, Sattineni & Bradford II (2011) also reported low adoption of BIM among estimators in the USA. A survey carried out by Tan (2011) and Ali, Al-Jamalullail & Boon (2013) also found that level of awareness is low among quantity surveyors (QS) in Malaysia.

In general, among the most cited barriers to BIM adoption is high cost of uptake (Azhar & Cochran, 2009; Malleson, 2012; McGraw Hill Construction, 2009; McGrawHill Construction - ME, 2011; Zhou *et* al, 2012; BCIS, 2012) and low awareness (Azhar & Cochran, 2009; Tan, 2011; Ali et al, 2013; CREAM, 2014). Furthermore, lack of clear guidance and strategies makes it more difficult for the firms/ organizations to adopt BIM (Gu & London, 2010; Azhar, Hein & Sketo, 2008; Lattifi et al, 2016). A study of BIM adoption among QS firms by Zhou *et* al (2012) found that high costs, unclear benefits, low motivation, low internal resources made them reluctant to adopt BIM. It is clear that there are some uncertainties surrounding the adoption of BIM by QS firms/ organisations and therefore, enhancing the success rate of its adoption has become an important issue.

As discussed previously, BIM has significant effects on productivity and quality. Hence, it is essential to understand the determinants of BIM adoption and the theoretical models that underlay IT adoption. Numerous studies have examined the factors that influences the adoption of BIM (See Chapter 2 for detail). Some studies have explored the barriers to adoption of BIM (Lee and Sexton, 2007; Brewer, Gajendran & Beard, 2009; Dobelis, 2013; Panuwatwanich & Peansupap, 2013; Stanley & Thurnell, 2013; von Both & Kindsvater, 2012; Memon et al, 2014) whilst others study the drivers of BIM adoption (Eadie, Browne, Odeyinka, McKeown & McNiff, 2013; Lee & Sexton, 2007; Panuwatwanich & Peansupap, 2013). In addition, there are also studies that look into the benefits and uses of BIM (von Both & Kindsvater, 2012; Won & Lee, 2010; Malleson, 2012; Newton & Chileshe, 2012; Yan & Demian, 2008; Olatunji *et al*, 2010; GhaffarianHoseini, Tookey, GhaffarianHoseini, Naismith, Azhar, Efimova & Raahemifar, 2017).

Nonetheless, there appears to be limited studies conducted on organizational adoption models of BIM. Enegbuma, Aliagha & Ali (2014) focuses on user perceptions of people, process and technology and their reactions to strategic IT implementation to explain BIM penetration. While a study by Lee (2013) explores the motivational factors of users and BIM acceptance using regression analysis. These studies investigate the acceptance of BIM at individual level. However, studies show that the adoption decision of ICT initiatives are made at the organizational level (Peansupap & Walker, 2006). Gallivan (2001) has argued that the initial adoption decision at organisational level is made by the authorities and the users are mandated