

DEVELOPMENT OF A BUILDING INFORMATION MODELLING (BIM)  
MIGRATION PATH MODEL FOR CONSTRUCTION PROFESSIONALS

JULIANA BINTI BRAHIM

A thesis submitted in  
fulfilment of the requirement for the award of the  
Doctor of Philosophy



Faculty of Technology Management and Business

Universiti Tun Hussein Onn Malaysia

JULY 2018

## DEDICATION

I dedicate this thesis

To my beloved Husband, **Ir. Zainidi bin Mat Yusoff**, thanks for your love and the countless hours of joy that we have shared throughout the years. This thesis could not be completed without your support, patient and dua'.

To my lovely daughter (**Nurul Hannah Diyanah**), my lovely son (**Muhammad Ali Imran**) and not forgetting my newborn baby (**Nurul Iman Hanani**) for your undying love, understanding and patient during this journey.

And in loving memory of my late father (**Brahim bin Mat Seran**), my mother (**Mariam binti Lop Yatin**) and siblings. Thank you for your loving and support of my dream.

## ACKNOWLEDGEMENTS

In the name of Allah, of going through this academic journey together was indeed very memorable. To Him, we belong and to Him, we will return. I wish to thank Him for all that He has gifted us, although He can never be praised or thanked enough.

I would like to express my appreciation to my supervisors Assoc. Prof. Dr. Aryani binti Ahmad Latiffi (Universiti Tun Hussein Onn Malaysia, UTHM) and Dr Mohamad Syazli bin Fathi (Universiti Teknologi Malaysia, Kuala Lumpur, UTM KL) for your help, guidance, moral support, time and patient to make this thesis a reality. It is an honour to work with them and a valuable experience through this journey.

I would like also to express my gratitude to all my respondents who have contributes to their valuable opinion and views for this research. I am totally thankful to the Ministry of Education (MoE) for their sponsorship and support throughout the study under MyBrain 15. Not forgetting to Office of Research, Innovation, Commercialisation and Consultancy (ORICC), UTHM, for supporting this research under the Exploratory Research Grant Scheme (ERGS), Vote No. E029. The list of thanks also goes to my research friends especially in UTHM, UTM Kuala Lumpur and Universiti Teknologi Mara (UiTM), Shah Alam Selangor for sharing knowledge and supporting each other through this journey.

I would like to express my biggest appreciation to my husband, Ir. Zainidi bin Mat Yusoff for being a superb supportive husband and best friend through this journey. I would like to give millions thank for being patient throughout these difficult years. There are no words could describe my gratitude towards your endless love and sacrifice to make this thesis a reality. Not forgetting to my lovely kids, Nurul Hannah Diyanah, Muhammad Ali Imran and my newborn baby, Nurul Iman Hanani. I am deeply sorry for not spending enough time through this journey. Finally, I would like to thank my mother, my family-in-law, my sister and my brothers for their prayers, support, love and understanding.

## ABSTRACT

The construction professionals have the notion that by implementing Building Information Modelling (BIM) in construction could overcome problems such as delay, cost overrun, clashes in project design and undesirable quality in construction. However, they failed to take the advantages of the BIM benefit as they are still trying to find the best way to take on board the BIM into current practices. Most of the professionals do not know 'when' and 'how' to apply BIM throughout the construction lifecycle. Several research models related to BIM has been developed to improve and encourage BIM implementation. Nevertheless, the developed models have limitations in highlighting the steps involved that could assist the construction professionals in implementing BIM effectively in Malaysia. Therefore, this research is aimed to develop a model that would be able to assist Malaysian construction professionals in implementing BIM in a structured way. A semi-structured interview was carried out with respondents that have various experienced and currently involved in BIM projects in the Malaysian construction industry. Findings show that the construction professionals are lacking in knowledge and experience in using BIM in various stages of construction. Thus, they were unable to fully capitalise the benefit of 3D models. Migration path model was proposed and evaluated as a strategic approach for BIM implementation in the Malaysian construction industry. The identification of five (5) activities (BIM Awareness, Develop BIM Strategy, Implement BIM, Monitor BIM and Expand BIM Implementation) with the three (3) enablers (BIM work contract, BIM work process and BIM technology) in the model is expected to be able to assist construction professionals to implement BIM with the right BIM concept and later, the benefit could be obtained for improving construction project. The proposed model could be as a guideline for construction professionals in implementing BIM, specifically in countries that new in BIM. The model is also expected to be able to fill the gap in BIM implementation by supporting the initiatives by the Malaysian government for increasing productivity in construction projects by using new technology like BIM.

## ABSTRAK

Pemodelan Maklumat Bangunan (*Building Information Modelling* (BIM)) memberi manfaat dan kebaikan kepada pasukan pembinaan bagi menangani masalah berkaitan kelewatan projek, lebih kos, masalah pertindihan antara rekabentuk projek dan kualiti kerja. Walau bagaimanapun, pasukan pembinaan gagal memperoleh manfaat dan kebaikan dari BIM kerana mereka masih lagi mencari cara-cara perlaksanaannya yang betul di dalam projek pembinaan. Dengan itu, beberapa model berkaitan BIM telah dibangunkan bagi membaiki dan menggalakkan pelaksanaan BIM. Walaubagaimanapun, model-model tersebut tidak menggambarkan aktiviti-aktiviti yang perlu dilakukan dalam membantu pasukan pembinaan melaksanakan BIM dengan berkesan di Malaysia. Oleh itu, kajian ini bertujuan untuk membangunkan model yang dapat membantu pasukan pembinaan melaksanakan BIM di dalam projek. Temubual separa struktur telah dilakukan bersama pasukan pembinaan yang terlibat dan mempunyai pengalaman dalam melaksanakan BIM di dalam projek pembinaan di industri pembinaan di Malaysia. Hasil dapatan kajian menunjukkan ketidaklancaran pelaksanaan BIM berlaku disebabkan oleh pasukan pembinaan yang terlibat kurang berpengalaman dan pengetahuan tentang pelaksanaan di fasa yang berbeza. Disebabkan itu, pasukan pembinaan tidak dapat memaksimumkan penggunaan dan kebaikan dari model 3D. Oleh yang demikian, model laluan migrasi telah dibangunkan dan dinilai sebagai pendekatan strategik bagi membantu dalam pelaksanaan BIM di Malaysia. Model tersebut mengandungi lima (5) aktiviti (Kesedaran tentang BIM, Pembangunan Strategi BIM, Pelaksanaan BIM, Pengawasan BIM dan Meluaskan Pelaksanaan BIM) bersama tiga (3) elemen (Kontrak Kerja BIM, Proses Kerja BIM dan Teknologi BIM) yang dapat membantu pasukan pembinaan dalam melaksanakan BIM dengan mengikuti konsep BIM, dan seterusnya aktiviti pembinaan dapat dibaiki melalui penggunaan BIM. Model ini juga diharapkan dapat menangani isu di dalam pelaksanaan BIM dengan menyokong inisiatif kerajaan Malaysia dalam meningkatkan produktiviti di dalam projek pembinaan menerusi BIM.

## CONTENTS

<b>TITLE</b>	<b>i</b>
<b>DECLARATION</b>	<b>ii</b>
<b>DEDICATION</b>	<b>iii</b>
<b>ACKNOWLEDGEMENT</b>	<b>iv</b>
<b>ABSTRACT</b>	<b>v</b>
<b>ABSTRAK</b>	<b>vi</b>
<b>CONTENTS</b>	<b>vii</b>
<b>LIST OF TABLES</b>	<b>xiv</b>
<b>LIST OF FIGURES</b>	<b>xvi</b>
<b>LIST OF ABBREVIATIONS</b>	<b>xviii</b>
<b>LIST OF APPENDICES</b>	<b>xx</b>
<b>CHAPTER 1 INTRODUCTION</b>	<b>1</b>
1.1 Introduction	1
1.2 Research Background	1
1.3 Problem Statement	3
1.4 Research Questions	6
1.5 Research Aim and Objectives	6
1.6 Research Scope	7
1.7 Research Significance	8
1.8 Research Process	9
1.8.1 First Stage: Research Identification	10
1.8.2 Second Stage: Review Research Topic	11
1.8.3 Third Stage: Research Methodology	11
1.8.4 Fourth Stage: Data Findings	12
1.8.5 Fifth Stage: Model Development	12
1.8.6 Sixth Stage: Conclusion and Recommendation	12
1.9 Thesis Organisation	12



1.10	Summary	14
<b>CHAPTER 2</b>	<b>BUILDING INFORMATION MODELLING (BIM)</b>	<b>15</b>
	<b>PRACTICES IN CONSTRUCTION PROJECTS</b>	
2.1	Introduction	15
2.2	The Development of Building Information Modelling (BIM) Definition	15
2.3	Building Information Modelling (BIM) in the Malaysian Construction Industry	22
2.4	Building Information Modelling (BIM) Uses in Construction Projects	29
2.5	Building Information Modelling (BIM) Work Process	32
2.6	The Implementation of Building Information Modelling (BIM) in Different Project Delivery Methods	37
2.7	Building Information Modelling (BIM) Software in Construction Projects	39
2.8	Roles of Construction Professionals in a Project Using Building Information Modelling (BIM)	41
2.9	Key Issues During Building Information Modelling (BIM) Implementation	47
2.9.1	The Understanding of the Building Information Modelling (BIM) Concept	48
2.9.2	Changes in Current Work Processes	50
2.9.3	Changes in the Legal Context	52
2.9.4	Adoption of New Technology	53
2.10	Key Elements in Building Information Modelling (BIM) Implementation	55
2.10.1	People Involved in Building Information Modelling (BIM) Projects	55
2.10.2	The Building Information Modelling (BIM) Work Process	57



	2.10.3 The Legal Context of Building Information Modelling (BIM)	59
	2.10.4 Building Information Modelling (BIM) Technology	60
	2.11 Summary	62
<b>CHAPTER 3</b>	<b>MATURITY AND MIGRATION PATH CONCEPT</b>	<b>63</b>
	3.1 Introduction	63
	3.2 Maturity and Migration Path Concept	63
	3.3 Review of Existing Model Related with Maturity and Migration Path Concept	65
	3.3.1 National Building Information Modelling Standard Capability Maturity Model (NBIMS-CMM)	65
	3.3.2 The Bew-Richards Building Information Modelling (BIM) Maturity Model	67
	3.3.3 The Virtual, Design and Construction (VDC) Scorecard	68
	3.3.4 Building Information Modelling Maturity Matrix (BIm3)	69
	3.3.5 Building Information Modelling (BIM) Quick Scan Tool	70
	3.3.6 The Organisational Building Information Modelling (BIM) Assessment Profile	70
	3.3.7 Indiana University (IU) Proficiency Matrix	71
	3.3.8 The Performance Measurement Migration Path Model	72
	3.3.9 BIM Maturity Measure (BIM-MM)	73
	3.3.10 The Owner BIM Competency Assessment Tool (BIM CAT)	74
	3.3.11 Building Information Modelling (BIM) Maturity Level for Design Stage	75
	3.4 Discussion of Existing Maturity and Migration Path Model	76





3.5	Adopted Migration Path Model of Building Information Modelling (BIM) for Construction Professionals	83
3.6	Proposed Conceptual Framework of Building Information Modelling (BIM) for Construction Professionals	85
3.7	Summary	86
<b>CHAPTER 4</b>	<b>RESEARCH METHODOLOGY</b>	<b>88</b>
4.1	Introduction	88
4.2	Research Concept	88
4.3	Classification of Research	89
4.3.1	Exploratory Studies	90
4.3.2	Descriptive Studies	90
4.3.3	Explanatory Studies	91
4.4	Designing the Research Methodological	91
4.5	Adopted Research Methodology	93
4.5.1	Research Philosophy	94
4.5.2	Research Approach	96
4.5.3	Research Strategies	97
4.5.4	Research Choices	98
4.5.5	Time Horizon	98
4.5.6	Research Procedures	99
4.5.6.1	Qualitative Data Collection	99
4.5.6.2	Qualitative Data Analysis	103
4.5.6.3	Model Development Process	108
4.6	Summary	110
<b>CHAPTER 5</b>	<b>DATA ANALYSIS AND DISCUSSION</b>	<b>111</b>
5.1	Introduction	111
5.2	Discussion of Data Gathered From Interviews	111
5.3	Respondent's Profile	112
5.3.1	Respondent' Designation	113



5.3.2	Respondents' Years of Experience in the Construction Industry and Projects Using Building Information Modelling (BIM)	114
5.4	Current Practices of Building Information Modelling (BIM) in the Malaysian Construction Industry	116
5.4.1	People in Building Information Modelling (BIM) Projects	116
5.4.1.1	Understanding of the Definition of Building Information Modelling (BIM)	116
5.4.1.2	Roles and Responsibilities of Construction Professionals in Project using Building Information Modelling (BIM)	120
5.4.2	Building Information Modelling (BIM) Work Process	135
5.4.2.1	Building Information Modelling (BIM) Uses in Construction Projects	136
5.4.2.2	Project Delivery Methods in Project Using Building Information Modelling (BIM)	141
5.4.2.3	Work Process in Design-Bid-Build (DBB) Projects	142
5.4.2.4	Work Process in Design and Build (D&B)	151
5.4.2.5	Work Process in Integrated Project Delivery (IPD)	156
5.4.3	Building Information Modelling (BIM) Work Contract	160



5.4.4	Building Information Modelling (BIM) Technology	162
5.4.4.1	Hardware in Projects using Building Information Modelling (BIM)	163
5.4.4.2	Building Information Modelling (BIM) Software	164
5.5	Challenges and Barriers in Implementing Building Information Modelling (BIM)	167
5.5.1	Lack of Understanding of Building Information Modelling (BIM)	167
5.5.2	Strategy for Building Information Modelling (BIM) Implementation are not Clearly Stated	179
5.5.2.1	Issues in Building Information Modelling (BIM) Work Contract	179
5.5.2.2	Issues in the Building Information Modelling (BIM) Work Processes	182
5.5.2.3	Issues in Building Information Modelling (BIM) Technology	184
5.5.3	The Implementation of Building Information Modelling (BIM) is in Chaos	185
5.6	Potential Improvements in Implementing Building Information Modelling (BIM)	191
5.6.1	Increase Building Information Modelling (BIM) Awareness	193
5.6.2	Develop Strategy for Building Information Modelling (BIM) Implementation	204
5.6.3	Implement Building Information Modelling (BIM) based on a Developed Strategy	215
5.6.4	Monitor Building Information Modelling (BIM) Implementation	218
5.6.5	Expand Building Information Modelling (BIM) Implementation	219
5.7	Discussion on Findings	220



5.8	Summary	228
<b>CHAPTER 6</b>	<b>MIGRATION PATH MODEL OF BUILDING INFORMATION MODELLING (BIM) FOR CONSTRUCTION PROFESSIONALS</b>	<b>229</b>
6.1	Introduction	229
6.2	Develop the Migration Path Model of Building Information Modelling (BIM) for Construction Professionals	229
6.2.1	Develop the Building Information Modelling (BIM) Maturity Model	230
6.2.2	Identify Enablers in the Maturity Model	236
6.2.3	Develop Details of the Migration Path Model of Building Information Modelling (BIM) for Construction Professionals	236
6.2.4	Develop Assessment of Maturity Level	238
6.2.4.1	Step 1: Identify Expected Outcome in Each Maturity Level	239
6.2.4.2	Step 2: Develop Score in Each Maturity Level	240
6.2.3.3	Step 3: Develop Details of the Assessment Questionnaire	241
6.3	Migration Path Model of Building Information Modelling (BIM) for Construction Professionals: How It Works	243
6.4	Users of the Migration Path Model	249
6.5	Model Evaluation	250
6.6	Evaluation Process	251
6.6.1	Interview Question Design	252
6.6.2	Choice of Evaluator	252
6.7	Evaluation Result and Analysis	253
6.7.1	Evaluators' Background	253
6.7.2	Content of the Research Model	254



6.7.3	Perceived Effectiveness of the Research Model	256
6.7.4	Usability of the Research Model	259
6.7.5	Benefits of the Research Model	260
6.7.6	Barriers in using the Research Model	263
6.7.7	Improvement for the Research Model	264
6.7.8	Limitation of the Research Model	266
6.8	Research Model Specification	267
6.9	Summary	268
<b>CHAPTER 7</b>	<b>CONCLUSION AND RECOMMENDATION</b>	<b>269</b>
7.1	Introduction	269
7.2	Research Overview	269
7.3	Research Conclusion	270
7.4	Research Contribution	274
7.5	Research Limitation	275
7.6	Recommendation for Future Research	277
7.7	Concluding Remark	278
	<b>REFERENCES</b>	<b>279</b>
	<b>APPENDICES</b>	<b>294</b>
	<b>LIST OF PUBLICATIONS</b>	<b>361</b>
	<b>VITA</b>	<b>363</b>



## LIST OF TABLES

2.1	The Development of the Term BIM	16
2.2	The BIM Definition	18
2.3	BIM Initiatives by Government Related Bodies	23
2.4	Focus of Government Related Bodies in BIM	28
2.5	Frequency of BIM Uses in Construction Project	30
2.6	BIM Software Use in Construction Project	39
2.7	Summary of Roles and Responsibilities of Construction Professionals in Projects using BIM	47
2.8	Summary of the Key Issues in Implementing BIM	54
2.9	Summary of Key Elements for BIM Implementation	61
3.1	NBIMS Capability Maturity Model	66
3.2	Summary of the Maturity and Migration Path Concept	77
3.3	Number of Maturity Levels in Models	78
3.4	Assessment Method for Selected Models	78
3.5	Strengthens and Limitation of Selected Model	80
3.6	Details of Five (5) Maturity Levels	84
3.7	Selected Enablers for Models	84
4.1	Research Strategies and Their Suitability	97
5.1	Respondents' Designations	113
5.2	Respondents' Experience in the Construction Industry and Project Using BIM	115
5.3	Understanding of BIM Definition	117
5.4	Roles and Responsibilities of a Client in a Project using BIM	121
5.5	Roles and Responsibilities of an Architect	122
5.6	Roles and Responsibilities of C&S Engineers	124
5.7	Roles and Responsibilities of M&E Engineers	126
5.8	Roles and Responsibilities of the Contractor	129

5.9	Roles and Responsibilities of a Facilities Manager	131
5.10	Roles and Responsibilities of a BIM Consultant	132
5.11	BIM Uses in Construction Projects	136
5.12	Project Delivery Methods in Projects Using BIM	141
5.13	Summary of the Work Process in Projects using BIM	158
5.14	Type of Contract used for Projects using BIM	160
5.15	BIM Software used in BIM Construction Projects	165
5.16	Design Consultants Work Separately	186
5.17	Late Appointment of Facilities Manager in Projects using BIM	188
5.18	Losses of Project Information	191
5.19	Duration of BIM Training	202
5.20	Developing a 3D Model at the Pre-Construction Phase	213
5.21	Expand BIM Technology	220
6.1	Description and Characteristic of Maturity Levels for BIM Implementation	231
6.2	Expected Outcome for Rubric Metric Assessment	240
6.3	Likert Scale for Assessment Purposes	241
6.4	Maturity Level Range Score and Action Needed	242
6.5	Summary of Model Users	250
6.6	Evaluators' Background in Projects Using BIM	253
6.7	Summary of the Evaluation of the Model Elements	260
6.8	Summary of the Benefits of the Model	262
6.9	Summary of the Model's Barriers	264
6.10	Summary of the Potential Improvements	266
6.11	Summary of the Limitation of Research Model	267
6.12	Research Model Specification	267



## LIST OF FIGURES

1.1	Research Process	10
2.1	Building Information Modelling (BIM) Development	16
2.2	The Development of the term BIM from 1977 to 2017	18
2.3	BIM Definition Timeline	22
2.4	25 Main BIM Uses in Construction Projects	29
2.5	RIBA Work Stage	33
2.6	Comparison of ‘Traditional DBB’ with ‘DBB with BIM’	37
2.7	Comparison of ‘Traditional D&B’ with ‘D&B with BIM’	38
3.1	The Bew-Richards BIM Maturity Model	67
3.2	VDC Scorecard BIM Score	68
3.3	Performance Measurement Migration Path Model	72
3.4	BIM CAT	74
3.5	BIM Implementation for Design Team	75
3.6	Summary of the Maturity and Migration Path Model	76
3.7	Proposed Migration Path Model of BIM for Construction Professionals	83
3.8	Conceptual Framework of BIM for Construction Professionals	85
4.1	Classification of Research	90
4.2	The Nested Approach	92
4.3	The Research Onion	92
4.4	The Modified Model	93
4.5	The Adopted Research Methodology	94
4.6	Research Procedures	100
4.7	The Process of Analysing Data using Atlas T.i.7	104
4.8	Add Document as a Primary Document	105
4.9	Creating Codes and Links	106
4.10	Coding Interview Transcription	107



4.11	Network View of Each Code	108
4.12	Process in Developing Migration Path Model for Implementing BIM for Construction Professionals	109
5.1	Respondents' Roles in Projects Using BIM	120
5.2	Summary of Roles and Responsibilities of Construction Professionals in Projects using BIM	135
5.3	BIM Process in Design-Bid-Build (DBB) Project at Pre-Construction Phase	143
5.4	BIM Process in Design-Bid-Build (DBB) Project at Construction Phase	147
5.5	BIM Process in Design-Bid-Build (DBB) Project at the Post-Construction Phase	150
5.6	BIM Process in Design and Build (D&B) Project at Pre-Construction Phase	152
5.7	BIM Work Process in Design and Build (D&B) Project at Construction Phase	155
5.8	BIM Work Process in IPD Project	156
5.9	Network View for the Lack of Understanding of BIM	168
5.10	Network View for Strategy for BIM is not Clearly Stated	179
5.11	Network View for Implementation of BIM is in Chaos	186
5.12	Network View of Potential Improvement for BIM Implementation	192
5.13	Atlas Network View for Increase BIM Awareness	195
5.14	Atlas Network View for Training on BIM Work Process	196
5.15	Atlas Network View for Develop BIM Strategy	205
5.16	Atlas Network View for Implement BIM Strategy	216
5.17	Key Findings on Challenges and Barriers with the Potential Improvements	227
6.1	BIM Maturity Model for Construction Professionals	231
6.2	Migration Path Model of BIM for Construction Professionals	237
6.3	Steps in Developing Assessment Questionnaire	239
6.4	Evaluation Process	251



## LIST OF ABBREVIATIONS

BIM	Building Information Modelling
2D	2-Dimensional
3D	3-Dimensional
4D	4-Dimensional
C&S	Civil and Structural
MEP	Mechanical, Electrical and Plumbing
QS	Quantity Surveyor
CIDB	Construction Industry Development Board
PWD	Public Works Department
PRIMA	PRIMA Corporation Malaysia
CREAM	Construction Research Institute of Malaysia
MSC	Multimedia Super Corridor
ABM	Akademi Binaan Malaysia
CIMP	Construction Industry Master Plan
MOW	Minister of Work
CITP	Construction Industry Transformation Programme
ICW	International Construction Week
MBKT	Majlis Perbandaran Kuala Terengganu
UMP	University of Malaysia Pahang
LOD	Level of Development
R&D	Research and Development
DBB	Design-Bid-Build
D&B	Design and Build
IPD	Integrated Project Delivery Method
NBIMS-	National Building Information Modelling Standard-Capability
CMM	Maturity Matrix
BIm3	Building Information Modelling Maturity Matrix Model

BDS	Building Description System
GLIDE	Graphical Language Interactive Design
BDM	Building Product Model
GBM	Generic Building Model
CABD	Computer Aided Building Design
AEC	Architecture, Engineering and Design
ICT	Information, Communication Technology
USA	United State of America
UK	United Kingdom
BEP	BIM Execution Plan
CMM	Capability Maturity Model
SEI	Software Engineering Institute
CLEVER	Cross-Sectoral Learning in the Virtual Enterprise
PM2	Project Management Process Maturity Model
SPICE	Standardised Process Improvement for Construction Enterprises
IT	Information and Technology
STEPS	Start-up, Take-Off, Expansion, Progressive, Sustainability
KM	Knowledge Management
VDC	Virtual, Design and Construction
BIM-MM	Building Information Modelling Maturity Measure
PM	Performance Measurement
IM	Information Management
IU	Indiana University
BIM CAT	Owner's BIM Competency Assessment Tool
VO	Variation Order
PEP	Project Execution Plan

## LIST OF APPENDICES

A	Description of BIM Uses	296
B	Building Information Modelling (BIM) Maturity Matrix (Bim3)	302
C	Interview Questions	306
D	Evaluation Questions	308
E	Annotation on DBB BIM Work Process	312
F	Annotation on D&B BIM Work Process	314
G	Annotation on IPD BIM Work Proses	316
H	Annotation on Perception of BIM as Software	317
I	Annotation on Lack of Skill in using BIM Software	318
J	Annotation on Excuse to Change to BIM	319
K	Annotation on Lack of Support by Top Management	320
L	Annotation on Uncertainty of Scope of Work of Construction Professionals	321
M	Annotation on Initiation of BIM at the Construction Phase	322
N	Annotation on Training related to BIM Work Contract	323
O	Annotation on Training related to BIM Work Process	324
P	Annotation of Training on Roles and Responsibilities of Construction Professionals	325
Q	Annotation on Training from Different Scope	326
R	Annotation on Training on BIM Technology	327
S	Annotation on the Need to Practise BIM Knowledge by Implementing in Trial Projects	328
T	Annotation on Roles of Top Management to Encourage BIM Implementation	329
U	Annotation on the need to Clarify Roles and Responsibilities of Construction Professionals	330

V	Annotation on Clarify Building Information Modelling (BIM) Uses of a Projects	331
W	Annotation on BEP in Projects using BIM	332
X	Annotation on Strategy on BIM Technology	333
Y	Annotation on the need to Collaborate and Communicate during BIM Implementation	334
Z	Annotation on the Need to Document Work Progress	335
AA	Annotation on The Need to Monitor BIM implementation	336
AB	Details of Assessment Question	337
AC	Annotation Benefit of Research Model	342
AD	Annotation on Research Model Provide as an Awareness to Construction Professionals	343
AE	Annotation on the Suitability of Maturity Level	344
AF	Annotation on Research Model Serves as a Good Improvement Process	345
AG	Annotation on Benefit of having Assessment Form with the Model	346
AH	Annotation on Suitability of Research Model	347
AI	Annotation on Suitability of Research Model to be used by an Organisation	348
AJ	Annotation on Capability of Research Model to Improve Capabilities of Construction Professionals in BIM	349
AK	Annotation on Benefit of Research Model in Assisting Top Management	350
AL	Annotation on the Need to Have Top Management	351
AM	Annotation on Issues related to Self-Assessment	352
AN	Annotation on the Need to Have Top Management to Utilise the Model	353
AO	Annotation on Evaluators Opinion on the Assessment Method	354
AP	Annotation on The Need to have People Aspect in the Model	355
AQ	Annotation on Limitation in Defining People Aspect	356
AR	Annotation on Lack of Details Explanation on the Enablers	357

AS	Annotation on Suitability of the Model for Construction Professionals with Less Experience in BIM	358
AT	Receipt of Thesis Proofread	359
AU	Turnitin Result	360



PTTA UTHM  
PERPUSTAKAAN TUNKU TUN AMINAH

## CHAPTER 1

### INTRODUCTION

#### 1.1 Introduction

This chapter introduces the background to the research and the problems that need to be addressed. It then goes on to present an outline of the research aim and objectives followed by a brief discussion of the research processes used in achieving them. The chapter ends with the organisation of the content for this thesis.

#### 1.2 Research Background

For the past ten years, projects over budget, project delays and poor quality of projects are typical problems that have been faced by the construction industry (Shehu *et al.*, 2014; Sinesilassie *et al.*, 2017). There are many issues that contributed to the problems such as design errors, late design changes, underestimating project cost, site acquisition problem and inappropriate contract strategy. Not limited to that, the use of 2-Dimensional (2D) documents and the involvement of various construction professional in projects also contributed to the problems. The use of 2D documents in producing designs has contributed to miscommunication, duplication of information and inaccurate information-sharing among construction professionals (Zakaria *et al.*, 2013; Goh *et al.*, 2014; Abbasnejad *et al.*, 2016). As a result, a client may have a problem with visualising a project design using drawings produced by architects, civil and structural (C&S) and mechanical, electrical and plumbing (MEP) engineers that may contain errors and clashes. The contractor may misinterpret the drawings and a

quantity surveyor (QS) may produce less-accurate project cost estimations based on the design (Eastman *et al.*, 2011; Bryde *et al.*, 2013; Crotty, 2013).

Furthermore, construction professionals specifically architects, engineers and contractors are unable to identify or predict any potential design clashes at the design stage between building components based on the 2D drawings (Reddy, 2011; Barati *et al.*, 2013; Crotty, 2013; Hardin and McCool, 2015). This is because, in conventional practice, the design clashes could only be identified when the construction has started. These problems may lead to project delays, cost overruns and low quality of the project as they need amendments to the project design and/or rectification work (Reddy, 2011; Azhar *et al.*, 2012; Zakaria *et al.*, 2013; Rahman *et al.*, 2016).

More importantly, the coordination of a large number of different construction professionals turns out to be a difficult task when utilising 2D-based workflows (Bryde *et al.*, 2013; Zakaria *et al.*, 2013; Mok *et al.*, 2015). This is because the client, architect and engineers (C&S and MEP) are working independently in producing the project design without coordinating their work with others (Crotty, 2013). As a result, these project designs do not fit with each other. They also contain errors, inaccuracies and are time-consuming to use (Crotty, 2013).

Therefore, Information and Communication Technology (ICT) is used as a potential solution to overcome the problems (Fulford and Standing, 2014; Shou *et al.*, 2015; Harun *et al.*, 2016) thus creating an opportunity to have an effective and efficient communication among construction professionals in construction projects (Bryde *et al.*, 2013). Building Information Modelling (BIM) uses ICT and is a modern practice in the Architecture, Engineering and Construction (AEC) industry to overcome problems in construction projects (PWD, 2011; Zakaria *et al.*, 2013; Aziz *et al.*, 2016; CIDB, 2016; Harun *et al.*, 2016). Malaysia has also been taking initiatives by mandating BIM practices in overcoming the problems for future construction projects as stated in the Construction Industry Transformation Programme (CITP) 2016-2020 (CIDB, 2016). BIM phenomena are expected to improve construction project planning by improving the quality of documentation as well as the constructability of the projects and hence influence the success of construction projects.

The capability of BIM to improve information on construction projects is also related to the use of BIM software (Morton, 2012; Luo and Liu, 2016) with the processes involved (Azhar *et al.*, 2012; Love *et al.*, 2015). Construction professionals could develop project information in a 3D model by using related software for



## REFERENCES

- Abanda, F., Manjia, M., Pettang, C., Tah, J. H. and Nkeng, G. (2016). Building Information Modelling in Cameroon: Overcoming Existing Challenges. *Civil and Environmental Engineering: Concepts, Methodologies, Tools, and Applications: Concepts, Methodologies, Tools, and Applications*: pp.145.
- Abanda, F., Vidalakis, C., Oti, A. and Tah, J. (2015). A Critical Analysis of Building Information Modelling Systems Used in Construction Projects. *Advances in Engineering Software*. 90: pp.183-201.
- Abbasnejad, B., Nepal, M. and Drogemuller, R. (2016). Key Enablers for Effective Management of BIM Implementation in Construction Firms. *Paper presented at the Proceedings of the CIB World Building Congress 2016: Volume I- Creating built environments of new opportunities*. TUT–Tampere University of Technology. pp. 622-633.
- Abdullah, S. A., Sulaiman, N., Ahmad Latiffi, A. and David, B. (2014). Building Information Modeling (BIM) from the Perspective of Facilities Management (FM) in Malaysia. *International Business Information Management Association, IBIMA*. pp. 1-16
- Associated of General Contractor, AGC. (2008). *AGC Contractors' Guide to BIM Version One*. Retrieved on November 10, 2014 from: [https://www.engr.psu.edu/ae/thesis/portfolios/2008/tjs288/Research/AGC\\_GuideToBIM.pdf](https://www.engr.psu.edu/ae/thesis/portfolios/2008/tjs288/Research/AGC_GuideToBIM.pdf)
- Ahmad Latiffi, A.(2012). *Performance Measurement For Construction Businesses*. Loughborough University; Ph.D. Thesis.
- Ahmad Latiffi, A., Brahim, J. and Fathi, M. S. (2014a). The Development of Building Information Modeling (BIM) Definition. *Applied Mechanics and Materials*. 567: pp.625-630.
- Ahmad Latiffi, A., Brahim, J. and Fathi, M. S. (2016). Transformation of Malaysian Construction Industry with Building Information Modelling (BIM). *Paper presented at the MATEC Web of Conferences*. EDP Sciences. pp. 00022.
- Ahmad Latiffi, A., Brahim, J., Mohd, S. and Fathi, M. S. (2014b). The Malaysian Government's Initiative in using Building Information Modeling (BIM) in Construction Projects. *Paper presented at the In Construction Projects Sustain, Solution, Structural Engineering Construction*, Bangkok. pp. 767-772.
- Ahmad Latiffi, A., Carrillo, P. M., Ruikar, K. and Anumba, C. J. (2010). Development of Performance Measurement Migration Path For Construction Organisations. *Third International Conference on Construction In Developing Countries (ICCIDC-III) "Advancing Civil, Architectural and Construction Engineering & Management"*

- Ahmad Latiffi, A., Mohd, S., Kasim, N. and Fathi, M. S. (2013). Building Information Modeling (BIM) Application in Malaysian Construction Industry. *International Journal of Construction Engineering and Management*. 2(A): pp.1-6.
- Akintola, A., Venkatachalam, S. and Root, D. (2017). New BIM Roles' Legitimacy and Changing Power Dynamics on BIM-Enabled Projects. *Journal of Construction Engineering and Management*. 143(9): pp.04017066.
- Alabdulqader, A., Panuwatwanich, K. and Doh, J.-H. (2013). Current Use of Building Information Modelling within Australian AEC Industry. *Paper presented at the Proceedings of the Thirteenth East Asia-Pacific Conference on Structural Engineering and Construction (EASEC-13)*. pp. C-3-1.
- Alaghandrad, A. (2015). *BIM Maturity Assessment and Certification in Construction Project Team Selection*. École de Technologie Supérieure; PhD Thesis.
- Alaghandrad, A., April, A., Forgues, D. and Leonard, M. (2015). BIM Maturity Assessment and Certification in Construction Project Team Selection. *Paper presented at the 5th International/11th Construction Speciality Conference*. Columbia.
- Alazmeh, N., Underwood, J. and Coates, S. (2017). Implementing a BIM collaborative workflow in the UK construction market. *International Journal of Sustainable Development and Planning*. 13(1): pp.24-35.
- Ali, K. N. and Boon, T. C. (2013). Building Information Modelling Awareness and Readiness Among Quantity Surveyors and Quantity Surveying Firms.
- Alreshidi, E., Mourshed, M. and Rezugui, Y. (2016). Requirements for Cloud-Based BIM Governance Solutions to Facilitate Team Collaboration in Construction Projects. *Requirements Engineering*: pp.1-31.
- Alreshidi, E., Mourshed, M. and Rezugui, Y. (2017). Factors for Effective BIM Governance. *Journal of Building Engineering*. 10: pp.89-101.
- Alshawi, M. (2007). *Rethinking IT in Construction and Engineering: Organisational Readiness*: Routledge.
- Ameziane, F. (2000). An Information System for Building Production Management. *International Journal of Production Economics*. 64(1): pp.345-358.
- Andersen, K. V. and Henriksen, H. Z. (2006). E-Government Maturity Models: Extension of the Layne and Lee Model. *Government Information Quarterly*. 23(2): pp.236-248.
- Arayici, Y., Coates, P., Koskela, L., Kagioglou, M., Usher, C. and O'Reilly, K. (2011). BIM Adoption and Implementation for Architectural Practices. *Structural survey*. 29(1): pp.7-25.
- Arayici, Y., Coates, P., Koskela, L., Kagioglou, M., Usher, C. and O'reilly, K. (2011). Technology Adoption in the BIM Implementation for Lean Architectural Practice. *Automation in Construction*. 20(2): pp.189-195.
- Ashworth, S., Tucker, M., Druhmman, C. and Kassem, M. (2016). Integration of FM Expertise and End User Needs in the BIM Process using the Employer's Information Requirements (EIR): *Working paper*. Liverpool John Moores University, Liverpool, 12.02.
- Autodesk. (2017). Revit: Built from BIM. Retrieved June 7, 2017 from <https://www.autodesk.com/products/revit-family/overview>
- Azhar, S. (2011). Building Information Modeling (BIM): Trends, Benefits, Risks, and Challenges for the AEC Industry. *Leadership and Management in Engineering* 11(3): pp.

- Azhar, S., Khalfan, M. and Maqsood, T. (2012). Building Information Modelling (BIM): Now and Beyond. *Australasian Journal of Construction Economics and Building*. 12(4): pp.15-28.
- Aziz, N. D., Nawawi, A. H. and Ariff, N. R. M. (2016). ICT Evolution in Facilities Management (FM): Building Information Modelling (BIM) as the Latest Technology. *Procedia-Social and Behavioral Sciences*. 234: pp.363-371.
- Azzouz, A., Copping, A., Shepherd, P. and Duncan, A. (2016a). Application of the ARUP BIM Maturity Measure: An Analysis of Trends and Patterns. *Paper presented at the annual conference of the Association of Researchers in Construction Management (ARCOM)*. Manchester.
- Azzouz, A., Copping, A., Shepherd, P. and Duncan, A. (2016b). Using the Arup BIM Maturity Measure to Demonstrate BIM Implementation in Practice. *Paper presented at the annual conference of the Association of Researchers in Construction Management (ARCOM)*. Manchester. pp. 5-7.
- Azzouz, A. and Hill, P. (2017). Hunting for perfection: How Arup measures BIM maturity on projects worldwide. *Construction Research and Innovation*. 8(2): pp.49-54.
- Babič, N. Č. (2016). Culture Change in Construction Industry: From 2D Toward BIM Based Construction. *Journal of Information Technology in Construction* pp.86-99.
- Badrinath, A. C., Chang, Y. T. and Hsieh, S. H. (2016). A Review of Tertiary BIM Education for Advanced Engineering Communication with Visualization. *Visualization in Engineering*. 4(1): pp.9.
- Barati, R., Charehzehi, A. and Preece, C. N. (2013). Enhancing Planning and Scheduling Program by Using Benefits of BIM-Based Applications. *Civil and Environmental Research*. 3(5): pp.41-48.
- Barison, M. B. and Santos, E. T. (2010). An Overview of BIM Specialists. *Computing in Civil and Building Engineering, Proceedings of the ICCCB2010*: pp.141.
- Barison, M. B. and Santos, E. T. (2011). The Competencies of BIM Specialists: A Comparative Analysis of the Literature Review and Job Ad Descriptions. *Paper presented at the Proc., Int. Workshop on Computing in Civil Engineering, ASCE, Reston, VA*.
- Barnes, P. and Davies, N. (2014). *BIM in Principle and in Practice*. London. ICE Publishing.
- Bazjanac, V. (2004). Virtual Building Environments (VBE)—Applying Information Modeling to Buildings, ECPPM—eWork and eBusiness in Architecture. *Engineering and Construction, Istanbul, Turkey*.
- Becerik-Gerber, B. and Kensek, K. (2009). Building information modeling in architecture, engineering, and construction: Emerging research directions and trends. *Journal of professional issues in engineering education and practice*. 136(3): pp.139-147.
- Bentley. (2017a). Project Information Management and Collaboration Cloud Services Retrieved June 6, 2017, from <https://www.bentley.com/en/products/brands/projectwise>
- Bentley. (2017b). Software for Infrastructure. Retrieved Jan 15, 2017, from <https://www.bentley.com/en/products>
- Björk, B.-C. (1989). Basic structure of a proposed building product model. *Computer-Aided Design*. 21(2): pp.71-78.
- Blumberg, B. F., Cooper, D. R. and Schindler, P. S. (2014). *Business Research Methods*. Berkshire: McGraw-hill education.

- Bosch-Sijtsema, P., Isaksson, A., Lennartsson, M. and Linderoth, H. C. (2017). Barriers and facilitators for BIM use among Swedish medium-sized contractors-“We wait until someone tells us to use it”. *Visualization in engineering*. 5(1): pp.3.
- Bryde, D., Broquetas, M. and Volm, J. M. (2013). The Project Benefits of Building Information Modelling (BIM). *International Journal of Project Management*. 31(7): pp.971-980.
- British Standard Institute, BSI. (2016). Building Information Modelling (BIM) Training Courses. Retrieved November 6, 2016 from: <https://www.bsigroup.com/en-GB/our-services/training-courses/BIM-training-courses/>
- Btoush, M. and Haron, A. (2017). Understanding BIM Adoption in the AEC Industry: The Case of Jordan. *Paper presented at the IOP Conference Series: Materials Science and Engineering*. IOP Publishing. pp. 012044.
- Campbell, D. A. (2007). Building Information Modeling: The Web3D Application for AEC. *Paper presented at the Proceedings of the twelfth international conference on 3D web technology*. ACM. pp. 173-176.
- Cao, D., Li, H. and Wang, G. (2014). Impacts of Isomorphic Pressures on BIM Adoption in Construction projects. *Journal of Construction Engineering and Management*. 140(12): pp.04014056.
- Cao, D., Li, H., Wang, G. and Huang, T. (2017). Identifying and contextualising the motivations for BIM implementation in construction projects: An empirical study in China. *International journal of project management*. 35(4): pp.658-669.
- Chen, K., Lu, W., Peng, Y., Zheng, L., Niu, Y. and Rowlinson, S. (2017) An Investigation of the Latent Barriers to BIM Adoption and Development. *Paper presented at the Proceedings of the 20th International Symposium on Advancement of Construction Management and Real Estate*. Springer. pp. 1007-1017.
- Chen, Y., Dib, H. and F. Cox, R. (2014). A Measurement Model of Building Information Modelling Maturity. *Construction Innovation*. 14(2): pp.186-209.
- Chien, K.-F., Wu, Z.-H. and Huang, S.-C. (2014). Identifying and Assessing Critical Risk Factors for BIM Projects: Empirical Study. *Automation in Construction*. 45: pp.1-15.
- Chin, L., Chai, C., Chong, H., Yusof, A. M. and Azmi, N. (2018). The Potential Cost Implications and Benefits from Building Information Modeling (BIM) in Malaysian Construction Industry. *Paper presented at the Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*. Springer. pp. 1439-1454.
- Choi, J., Kim, H. and Kim, I. (2015). Open BIM-based Quantity Take-Off System for Schematic Estimation of Building Frame in Early Design Stage. *Journal of Computational Design and Engineering*. 2(1): pp.16-25.
- Chong, H.-Y., Lee, C.-Y. and Wang, X. (2017). A Mixed Review of the Adoption of Building Information Modelling (BIM) for Sustainability. *Journal of Cleaner Production*. 142: pp.4114-4126.
- Construction Industry Development Board, CIDB. (2014). BIM Roadmap for Malaysian Construction Industry: Workshop Report (Series 2). pp.1-21.
- Construction Industry Development Board, CIDB. (2015a). *BIM Steering Committee* Retrieved 31 December, 2016, from: <http://www.bimcenter.com.my/wp-content/uploads/2015/01/roadmapreport2.pdf>



- Construction Industry Development Board, CIDB. (2015b). MyBIM Malaysia. Retrieved on January 10, 2017 from: <http://www.bimcenter.com.my/>
- Construction Industry Development Board, CIDB. (2016). *Construction Industry Transformational Programme, (CITP)* Retrieved 10 January, 2017, from: <http://www.citp.my/about/>
- Clark, T. and Jones, R. (1999). Organisational interoperability maturity model for C2. *Paper presented at the Proceedings of the 1999 Command and Control Research and Technology Symposium.*
- Construction Specifications Institute, C. (2011). *The CSI Construction Contract Administration Practice Guide*: John Wiley.
- Construction Research Institute of Malaysia, CREAM. (2014). *Issues and Challenges in Implementing BIM For SME's in the Construction Industry*. Retrieved 1 January 2015, from: <http://www.cidb.gov.my/cidbv4/images/pdf/announcement/BIM/bim%20seminar%20%20workshop%20for%20malaysia%20construction%20industry.pdf>
- Creswell, J. W. (2014). *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*: SAGE Publications.
- Crotty, R. (2013). *The Impact of Building Information Modelling: Transforming Construction*: Routledge.
- Davies, K., Davies, K., McMeel, D. J., McMeel, D. J., Wilkinson, S. and Wilkinson, S. (2017). Making Friends with Frankenstein: Hybrid Practice in BIM. *Engineering, Construction and Architectural Management*. 24(1): pp.78-93.
- Davies, K., McMeel, D. and Wilkinson, S. (2015). Soft Skill Requirements in a BIM Project Team. *Proceedings of the 32nd International Conference of CIB W78* pp.108-117.
- Dawood, N. and Vukovic, V. (2015). Whole Lifecycle Information Flow Underpinned by BIM: Technology, Process, Policy and People. *2nd International Conference on Civil and Building Engineering Informatics*. pp.1-7
- Demirdoven, J. and Arditi, D. (2014). Advancing BIM in the Construction Management and Engineering Curriculum. *Paper presented at the Proceedings of 11th International Congress on Advances in Civil Engineering*. pp. 21-25.
- Díaz-Vilariño, L., Lagüela, S. and Varela, M. (2016). BIM as Management Tool for Existing Buildings. *Non-Destructive Techniques for the Evaluation of Structures and Infrastructure*. 11: pp.377.
- Dib, H., Chen, Y. and Cox, R. (2012) A Framework for Measuring Building Information Modeling Maturity based on Perception of Practitioners and Academics Outside the USA. *Paper presented at the Proceedings 29th of the CIB W78 2012: 29th International Conference Beirut, Lebanon*. pp. 17-19.
- Ding, L., Zhou, Y. and Akinci, B. (2014). Building Information Modeling (BIM) Application Framework: The Process of Expanding From 3D to Computable nD. *Automation in Construction*. 46: pp.82-93.
- Ding, Z., Zuo, J., Wu, J. and Wang, J. (2015). Key factors for the BIM adoption by architects: A China study. *Engineering, Construction and Architectural Management*. 22(6): pp.732-748.
- Dobelis, M. (2013) Drawbacks of BIM (Building Information Modelling) concept adoption. *Paper presented at the International Conference: Engineering Graphics BALTRAF 2013, 12, Riga (Latvia), 5-7 Jun 2013*. Riga Technical University.
- Dossick, C. S. and Neff, G. (2008). How Leadership Overcomes Organizational Divisions in BIM-Enabled Commercial Construction. *LEAD 2008*.

- Eadie, R., Browne, M., Odeyinka, H., McKeown, C. and McNiff, S. (2013). BIM Implementation Throughout the UK Construction Project Lifecycle: An Analysis. *Automation in Construction*. 36: pp.145-151.
- Eadie, R., McLernon, T. and Patton, A. (2015a). A Survey of Current Status of and Perceived Changes Required for BIM Adoption in the UK. *Built Environment Project and Asset Management*. 5(1): pp.4-21.
- Eadie, R., McLernon, T. and Patton, A. (2015b). An Investigation into the Legal Issues Relating to Building Information Modelling (BIM). *Proceedings of RICS COBRA AUBEA 2015*.
- Eastman, C. (1980). System Facilities for CAD Databases. *Paper presented at the Proceedings of the 17th Design Automation Conference*. ACM. pp. 50-56.
- Eastman, C. and Henrion, M. (1977). Glide: A Language for Design Information Systems. *Paper presented at the ACM SIGGRAPH Computer Graphics*. ACM. pp. 24-33.
- Eastman, C. and Jeng, T. S. (1999). A Database Supporting Evolutionary Product Model Development for Design. *Automation in Construction*. 8(3): pp.305-323.
- Eastman, C., Lee, G. and Sacks, R. (2003). Development of a Knowledge-rich CAD System for the North American Precast Concrete Industry. *Paper presented at the ACADIA*. pp. 208-215.
- Eastman, C., Lividini, J. and Stoker, D. (1975). A Database for Designing Large Physical Systems. *Paper presented at the Proceedings of the May 19-22, 1975, national computer conference and exposition*. ACM. pp. 603-611.
- Eastman, C., Teicholz, P. and Sacks, R. (2011). *BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers and Contractors*: John Wiley & Sons.
- Eastman, C. M. and Siabiris, A. (1995). A generic building product model incorporating building type information. *Automation in construction*. 3(4): pp.283-304.
- Elmualim, A. and Gilder, J. (2014). BIM: innovation in design management, influence and challenges of implementation. *Architectural Engineering and design management*. 10(3-4): pp.183-199.
- Enebuma, W., Aliagha, G. and Ali, K. (2015). Effects of Perceptions on BIM Adoption in Malaysian Construction Industry. *Journal of Technology*. 77(15): pp.69-75.
- Economic Planning Unit, EPU. (2016). *Malaysian Productivity Blueprint: Driving Productivity of the Nation*. from: [http://epu.gov.my/sites/default/files/MPB\\_Chapter-3.pdf](http://epu.gov.my/sites/default/files/MPB_Chapter-3.pdf)
- Fellows, R. F. and Liu, A. M. M. (2015). *Research Methods for Construction*: Wiley.
- Fenves, S. J. and Rasdorf, W. J. (1982). *Role of database management systems in structural engineering*. Paper presented at the International Association of Bridge and Structural Engineer Symposium on Informatics in Structural Engineering, Bergamo, Italy.
- Fountain, J. W. (2016). *Outsourcing of Building Information Modeling (BIM) Among General Contractors in the United States*. University of Southern Mississippi. Honor Thesis.
- Fulford, R. and Standing, C. (2014). Construction Industry Productivity and the Potential for Collaborative Practice. *International Journal of Project Management*. 32(2): pp.315-326.

- Garber, R. (2014). *BIM Design: Realising the Creative Potential of Building Information Modelling* (Vol. 2): John Wiley & Sons.
- Gardner, J. C., Hosseini, M. R., Rameezdeen, R. and Chileshe, N. (2014) Building Information Modelling (BIM) Education in South Australia: Industry Needs. *Paper presented at the 5th International Conference on Engineering, Project, and Production Management (EPPM 2014)*. pp. 293-302.
- Gerges, M., Austin, S., Mayouf, M., Ahiaikwo, O., Jaeger, M., Saad, A. and Gohary, T.-E. (2017). An Investigation Into the Implementation of Building Information Modeling in the Middle East. *Journal of Information Technology in Construction (ITcon)*. 22(1): pp.1-15.
- Ghaffarianhoseini, A., Tookey, J., Ghaffarianhoseini, A., Naismith, N., Azhar, S., Efimova, O. and Raahemifar, K. (2016). Building Information Modelling (BIM) Uptake: Clear benefits, Understanding its Implementation, Risks and Challenges. *Renewable and Sustainable Energy Reviews*. pp. 1046-1053.
- Gholami, E., Kiviniemi, A., Kocaturk, T. and Sharples, S. (2015). Exploiting BIM in Energy Efficient Domestic Retrofit: Evaluation of Benefits and Barriers. *Paper presented at the Proceeding of the 2nd International Conference on Civil And Building Engineering Informatics*. pp 1-8
- Giel, B. and Issa, R. R. A. (2016). Framework for Evaluating the BIM Competencies of Facility Owners. *Journal of Management in Engineering*. 32(1).
- Gledson, B., Hilton, D. and Rogage, K. (2016). Benchmarking BIM Levels of Training and Education amongst Construction Management Practitioners.
- Goh, K. C., Goh, H. H., Toh, S. and Peniel Ang, S. (2014). Enhancing Communication in Construction Industry through BIM. *Paper presented at the In: Proceedings of the 11th International Conference of Innovation and Management (ICIM 2014)*, Vaasa, Finland.
- Goulding, J. S., Rahimian, F. P. and Wang, X. (2014). Virtual reality-based cloud BIM platform for integrated AEC projects. *Journal of Information Technology in Construction (ITCON)*. 19(18): pp.308-325.
- Gourlis, G. and Kovacic, I. (2017). Building Information Modelling for Analysis of Energy Efficient Industrial Buildings—A Case Study. *Renewable and Sustainable Energy Reviews*. 68: pp.953-963.
- Govender, K., Nyagwachi, J., Smallwood, J. and Allen, C. (2018). The Awareness Of Integrated Project Delivery And Building Information Modelling-Facilitating Construction Projects. *International Journal of Sustainable Development and Planning*. 13(1): pp.121-129.
- Grilo, A. and Jardim-Goncalves, R. (2010). Value proposition on interoperability of BIM and collaborative working environments. *Automation in Construction*. 19(5): pp.522-530.
- Grover, R. and Froese, T. M. (2016). Knowledge Management in Construction Using a SocioBIM Platform: A Case Study of AYO Smart Home Project. *Procedia Engineering*. 145: pp.1283-1290.
- Gu, N. and London, K. (2010). Understanding and Facilitating BIM Adoption in the AEC Industry. *Automation in Construction*. 19(8): pp.988-999.
- Hadzaman, N. A. H., Takim, R. and Mohammad, A. H. N. M. F. (2016). An Exploratory Study: Building Information Modelling Execution Plan (BEP) Procedure in Mega Construction Projects. *Malaysian Construction Research Journal*. 18(1): pp.29-40.

- Hadzaman, N. A. H., Takim, R. and Nawawi, A. H. (2015). BIM Roadmap Strategic Implementation Plan: LEsson Learnt From Australia, Singapore and Hong Kong. *Procs 31st Annual ARCOM Conference*: pp. 611-620.
- Hardin, B. and McCool, D. (2015). *BIM and Construction Management: Proven Tools, Methods, and Workflows*. Indiana: John Wiley & Sons.
- Haron, A. T.(2013). *Organisational Readiness to Implement Building Information Modelling: A Framework for Design Consultants in Malaysia*. University of Salford Manchester; Doctor of Philosophy.
- Haron, N. A., Soh, R., Ana, R. P. Z. and Harun, A. N. (2017). Implementation of Building Information Modelling (BIM) in Malaysia: A Review. *Pertanika Journal of Science & Technology*. 25(3). pp. 661-674.
- Harun, A. N., Samad, S. A., Mohd Nawi, M. N. and Haron, N. A. (2016). Existing Practices of Building Information Modeling (BIM) Implementation in the Public Sector. *International Journal of Supply Chain Management*. 5(4): pp.166-177.
- Hayes, E. and Saleeb, N. (2016). The Virtual Interactive Relationship Between BIM Project Teams: Effective Communication to aid Collaboration in the Design Process.
- Hjelseth, E. (2015). Integrated Approaches for Implementing Building Information Modelling (BIM) in Engineering Education. *Paper presented at the Interdisciplinary education in a connected world, 8th International Conference on Engineering & Business Education (ICEBE) at Østfold University College, Fredrikstad, Norway*.
- Hjelseth, E. and Mêda, P. (2017). Is BIM-based Product Documentation Based on Applicable Principles?—Practical use in Norway and Portugal. *Paper presented at the eWork and eBusiness in Architecture, Engineering and Construction: ECPPM 2016: Proceedings of the 11th European Conference on Product and Process Modelling (ECPPM 2016), Limassol, Cyprus, 7-9 September 2016*. CRC Press. pp. 399.
- Ho, D., Kumar, A. and Shiwakoti, N. (2016). Maturity Model for Supply Chain Collaboration: CMMI Approach. *Paper presented at the Industrial Engineering and Engineering Management (IEEM), 2016 IEEE International Conference on*. IEEE. pp. 845-849.
- Hsieh, P.J., Lin, B. and Lin, C. (2009) The Construction and Application of Knowledge Navigator Model (KNM™): An Evaluation of Knowledge Management Maturity. *Experts Systems with Application*. 2 (36) pp. 4087-4100.
- Jin, R., Hancock, C. M., Tang, L. and Wanatowski, D. (2017). BIM Investment, Returns, and Risks in China's AEC Industries. *Journal of Construction Engineering and Management*. 143(12): pp.04017089.
- Jin, R., Tang, L. and Fang, K. (2015). Investigation into the current stage of BIM application in China's AEC industries. *WIT Transactions on The Built Environment*. 149: pp.493-503.
- Jung, W. and Lee, G. (2015). The Status of BIM Adoption on Six Continents. *International Journal of Civil, Environmental, Structural, Construction and Architectural Engineering*. 9(5): pp.444-448.
- Kam, C., Senaratna, D., McKinney, B., Xiao, Y. and Song, M. (2013). The VDC Scorecard: Formulation and Validation. *Center for Integrated Facility Engineering: Stanford University*.



- Kamara, J. M., Anumba, C. J. and Carrillo, P. M. (2002). A CLEVER approach to selecting a knowledge management strategy. *International journal of project management*. 20(3): pp.205-211.
- Kang, S., Ha, J., Ju, T. and Jung, Y. (2016). Interoperability Analysis for BIM Software Based on User-Defined Properties. *Korean Journal of Construction Engineering and Management*. 17(2): pp.99-109.
- Kassem, M., Iqbal, N., Kelly, G., Lockley, S. and Dawood, N. (2014). Building Information Modelling: Protocols for Collaborative Design Processes. *Journal of Information Technology in Construction (ITcon)*. 19: pp.126-149.
- Kassem, M., Kelly, G., Dawood, N., Serginson, M. and Lockley, S. (2015). BIM in facilities management applications: a case study of a large university complex. *Built Environment Project and Asset Management*. 5(3): pp.261-277.
- Kassem, M., Vukovic, V., Dawood, N., Hafeez, A., Chahrour, R. and Naji, K. (2016). Approaches for Assessing BIM Adoption in Countries: a Comparative Study within Qatar.
- Kensek, K. M. (2014). *Building Information Modeling*: Routledge.
- Kerosuo, H., Miettinen, R., Paavola, S., Mäki, T. and Korpela, J. (2015). Challenges of the Expansive use of Building Information Modeling (BIM) in Construction Projects. *Production*. 25(2): pp.289-297.
- Kerosuo, H. and Paavola, S. (2016). Expansive Uses of BIM and Organizing BIM Coordination. *WHEN SOCIAL SCIENCE MEETS LEAN AND BIM*: pp.27.
- Khosrowshahi, F. and Arayici, Y. (2012). Roadmap for Implementation of BIM in the UK Construction Industry. *Engineering, Construction and Architectural Management*. 19(6): pp.610-635.
- Kim, K. P., Ma, T., Baryah, A. S., Zhang, C. and Hui, K. M. (2016). Investigation of Readiness for 4D and 5D BIM Adoption in the Australian Construction Industry. *Management Review: An International Journal*. 11(2): pp.43.
- Kiviniemi, A. and Codinhoto, R. (2014). Challenges in the Implementation of BIM for FM—Case Manchester Town Hall Complex. *Computing in Civil and Building Engineering (2014)*: pp.665-672.
- Knotten, V. and Svalestuen, F. (2000). Implementing Virtual Design and Constructon (VDC) in Veidekke—Using Simple Metrics to Improve the Design Management Process.
- Kokkonen, A. and Alin, P. (2016). Practitioners Deconstructing and Reconstructing Practices when Responding to the Implementation of BIM. *Construction Management and Economics*. 34(7-8): pp.578-591.
- Korpela, J., Miettinen, R., Salmikivi, T. and Ihalainen, J. (2015). The Challenges and Potentials of Utilizing Building Information Modelling in Facility Management: The Case of the Center for Properties and Facilities of the University of Helsinki. *Construction Management and Economics*. 33(1): pp.3-17.
- Kreider, R., Messner, J. and Dubler, C. (2010). Determining the Frequency and Impact of Applying BIM for Different Purposes on Projects. *Paper presented at the Proceedings of the 6th International Conference on Innovation in Architecture, Engineering & Construction (AEC)*. pp. 9-11.
- Krygiel, E. and Nies, B. (2008). *Green BIM: Successful Sustainable Design with Building Information Modeling*: John Wiley & Sons.
- Ku, K. and Taiebat, M. (2011). BIM Experiences and Expectations: The Constructors' Perspective. *International Journal of Construction Education and Research*. 7(3): pp.175-197.

- Latiffi, A. A., Mohd, S., Kasim, N. and Fathi, M. S. (2013). Building Information Modeling (BIM) Application in Malaysian Construction Industry. *International Journal of Construction Engineering and Management*. 2(A): pp.1-6.
- Lee, G., Sacks, R. and Eastman, C. M. (2006). Specifying parametric building object behavior (BOB) for a building information modeling system. *Automation in construction*. 15(6): pp.758-776.
- Li, H., Ng, S. T., Skitmore, M., Zhang, X. and Jin, Z. (2017) Barriers to Building Information Modelling in the Chinese Construction Industry. *Paper presented at the Proceedings of the Institution of Civil Engineers-Municipal Engineer*. ICE Publishing. pp. 105-115.
- Liang, C., Lu, W., Rowlinson, S. and Zhang, X. (2016). Development of a Multifunctional BIM Maturity Model. *Journal of Construction Engineering and Management*: pp.06016003.
- Lin, Y.-C. and Yang, H.-H. (2018). A Framework for Collaboration Management of BIM Model Creation in Architectural Projects. *Journal of Asian Architecture and Building Engineering*. 17(1): pp.39-46.
- Lindblad, H. (2013). Study of the Implementation Process of BIM in Construction Projects.
- Liu, M. (2013). Investigation of the Impact of BIM&IPD on Change Orders using Bayesian Network Method. In H. Zhao, K. Liu and X. Yu (Eds.), *Advanced Design and Manufacturing Technology Iii, Pts 1-4* Stafa-Zurich: Trans Tech Publications Ltd Vol. 397-400. pp. 2064-2068
- Liu, Y., van Nederveen, S. and Hertogh, M. (2016). Understanding Effects of BIM on Collaborative Design and Construction: An Empirical Study in China. *International Journal of Project Management*.
- Liu, Y., van Nederveen, S. and Hertogh, M. (2017). Understanding Effects of BIM on Collaborative Design and Construction: An Empirical Study in China. *International Journal of Project Management*. 35(4): pp.686-698.
- Lockamy III, A. and McCormack, K. (2004). The Development of a Supply Chain Management Process Maturity Model using the Concepts of Business Process Orientation. *Supply Chain Management: An International Journal*. 9(4): pp.272-278.
- Love, P., Zhou, J., Matthews, J., Sing, C.-P., Olatunji, O. and Carey, B. (2015). Discussion of “State of Practice of Building Information Modeling in the Electrical Construction Industry” by Awad S. Hanna, Michael Yeutter, and Diane G. Aoun. *Journal of Construction Engineering and Management*. 142(3): pp.07015001.
- Lu, N. and Korman, T. (2010). Implementation of Building Information Modeling (BIM) in Modular Construction: Benefits and Challenges. *Paper presented at the Proceedings of the Construction Research Congress, Banff, Alta*. pp. 8-10.
- Luo, Y. and Liu, Y. (2016) BIM for Bridge Design. *Paper presented at the IABSE Symposium Report*. International Association for Bridge and Structural Engineering. pp. 343-350.
- Mancini, M., Wang, X., Skitmore, M. and Issa, R. (2017). Editorial for IJPM Special Issue on advances in building information modeling (BIM) for construction projects: Elsevier.
- McAuley, B., Hore, A. and West, R. (2015). The Development of Key Performance Indicators to Monitor Early Facilities Management Performance Through the Use of BIM Technologies in Public Sector Projects.

- McCuen, T. L., Suermann, P. C. and Krogulecki, M. J. (2011). Evaluating Award-Winning BIM Projects using the National Building Information Model Standard Capability Maturity Model. *Journal of Management in Engineering*. 28(2): pp.224-230.
- McIntosh, H. J. B. J. F. (1984). Research Directions in Computer-Aided Building Design. *Paper presented at the U.S-U.K Joint Workshop on Architectural Research Reading*, United Kingdom. pp. 104-113.
- Meadati, P. K. (2007). *Integration of Construction Process Documents into Building Information Modeling: The University of Nebraska-Lincoln*.
- Meng, X., Sun, M. and Jones, M. (2011). Maturity Model for Supply Chain Relationships in Construction. *Journal of Management in Engineering*. 27(2): pp.97-105.
- Merschbrock, C. and Munkvold, B. E. (2015). Effective Digital Collaboration in the Construction Industry—A Case Study of BIM Deployment in a Hospital Construction Project. *Computers in Industry*. 73: pp.1-7.
- Merschbrock, C. and Nordahl-Rolfsen, C. (2015). Managing Expectations of BIM Product Quality: A ‘Lemon Market’ Theory View. *WIT Transactions on The Built Environment*. 149: pp.253-264.
- Miettinen, R. and Paavola, S. (2014). Beyond the BIM Utopia: Approaches to the Development and Implementation of Building Information Modeling. *Automation in construction*. 43: pp.84-91.
- Migilinskas, D., Popov, V., Juocevicius, V. and Ustinovichius, L. (2013). The Benefits, Obstacles and Problems of Practical BIM Implementation. *Procedia Engineering*. 57: pp.767-774.
- Mohd Ashhar, S. M. (2017). *Perlaksanaan BIM di Jabatan Kerja Raya*. Retrieved July 11, 2017, from: [http://www.architecturemalaysia.com/Files/Pool/90\\_170525\\_1641444144\\_bim\\_in\\_jkr\\_cidb\\_p](http://www.architecturemalaysia.com/Files/Pool/90_170525_1641444144_bim_in_jkr_cidb_p)
- Mohd, S.(2015). *Building Information Modelling (BIM) Implementation Model for Construction Project Design Stage*. Universiti Tun Hussein Onn Malaysia.
- Mohd, S., Brahim, J., Ahmad Latiffi, A., Fathi, M. S. and Harun, A. N. (2016). Developing Building Information Modelling (BIM) Implementation Model for Project Design Team. *Paper presented at the International Conference on Innovation and Management, 2016*, Malaysia-Japan International Institute Of Technology (MJIT) of Universiti Teknologi Malaysia (UTM). pp. pp. 119-129.
- Mohd Tobi, S. U. (2016). *Qualitative Research, Interview Analysis & NVivo 11 Exploration*. Malaysia: ARAS Publisher.
- Mok, K. Y., Shen, G. Q. and Yang, J. (2015). Stakeholder Management Studies in Mega Construction Projects: A Review and Future Directions. *International Journal of Project Management*. 33(2): pp.446-457.
- Monteiro, A. and Martins, J. P. (2013). A Survey on Modeling Guidelines for Quantity Takeoff-Oriented BIM-Based design. *Automation in Construction*. 35: pp.238-253.
- Monteiro, A. and Martins, J. P. P. (2012). BIM Modeling for Contractors-Improving Model Takeoffs. *Paper presented at the CIB W078 29th International Conference on Applications of it in the AEC Industry*.
- Morton, D. E. (2012). BIM: A Transformative Technology within the Architectural Curriculum in Schools of Architecture (Pedagogic Stages of Architectural Education and the Transformative Effect of BIM). *International Journal of 3-D Information Modeling (IJ3DIM)*. 1(4): pp.50-68.

- Multimedia Super Corridor, MSC. (2016). *What is MSC Malaysia?*. Retrieved May 7, 2017 from: [http://www.msomalaysia.my/what\\_is\\_msc\\_malaysia](http://www.msomalaysia.my/what_is_msc_malaysia)
- Nagalingam, G., Jayasena, H. S. and Ranadewa, K. (2013). Building Information Modelling and future quantity surveyor's practice in Sri Lankan construction industry. *Paper presented at the Second World Construction Symposium*. pp. 81-92.
- Nath, T., Attarzadeh, M. and Tiong, R. L. (2016). Precast Workflow Productivity Measurement through BIM Adoption. *Proceedings of the Institution of Civil Engineers-Management, Procurement and Law*. 169(5). pp.208-216.
- National Building Information Modelling Standard, NBIMS. (2007). *National Building Information Modeling Standard Version 1 Part 1: Overview, Principles and Methodologies*. Retrieved February 10, 2014, from:
- Newton, K. and Chileshe, N.(2012). *Awareness, Usage and Benefits of Building Information Modelling (BIM) Adoption-The Case of the South Australian Construction Organisations*. Association of Researchers in Construction Management.
- Paulk, M. (1993). *Capability Maturity Model for Software*: Wiley Online Library.
- Penttilä, H. (2006). Describing the changes in architectural information technology to understand design complexity and free-form architectural expression. *Journal of Information Technology in Construction (ITcon)*. 11(29): pp.395-408.
- Pejabat Naib Chanselor, PNC. (2015). *UMP Meterai Kerjasama dengan JKR Malaysia bagi Pembangunan BIM dalam Industri Binaan*. Retrieved July 11, 2017, from: <http://community.ump.edu.my/ecomstaff/includes/viewNewsToPublic.jsp?ref=18925>
- Porwal, A. and Hewage, K. N. (2013). Building Information Modeling (BIM) Partnering Framework for Public Construction Projects. *Automation in Construction*. 31: pp.204-214.
- PRIMA, P. M. C. M. (2017). *About Prima*. Retrieved May 2, 2017, from: <http://www.prima.my/about.php?lang=en>
- Computer Integrated Construction Research Group (2010). *BIM Project Execution Planning Guide Version 2.0*. Retrieved June 10, 2017 from: [https://vdc.scorecard.stanford.edu/sites/default/files/BIM\\_Project%20Execution%20Planning%20Guide-v2.0.pdf](https://vdc.scorecard.stanford.edu/sites/default/files/BIM_Project%20Execution%20Planning%20Guide-v2.0.pdf)
- Computer Integrated Construction Research Group (2013). *BIM Planning Guide for Facility Owners. Version 2.0*. Retrieved June 10, 2017 from: [http://bim.psu.edu/resources/owner/bim\\_planning\\_guide\\_for\\_facility\\_owners-version\\_2.0.pdf](http://bim.psu.edu/resources/owner/bim_planning_guide_for_facility_owners-version_2.0.pdf)
- Puolitaival, T., Kestle, L., Davies, K. and Forsythe, P. (2015). Assessment in virtual design and construction education.
- Public Work Department, PWD. (2013). Unit Building Information Modelling (BIM) from [https://www.jkr.gov.my/prokom/index.php?option=com\\_content&view=article&id=84&Itemid=435&lang=ms](https://www.jkr.gov.my/prokom/index.php?option=com_content&view=article&id=84&Itemid=435&lang=ms)
- Public Work Department, PWD. (2014). *Garis Panduan BIM JKR*.
- Public Work Department, PWD. (2015). *Manual Proses Kerja BIM JKR : Fasa Perancangan*. Cawangan Perancangan Aset Bersepadu.
- Quinn, C.(2015). *A Critical Review of BIM for FM with an Emphasis on Offices*. Dublin Institute of Technology. Master Programme.
- Rahman, H. A., Chen, W. and Hui, J. Y. B. (2016). Impacts of Design Changes on Construction Project Performance: Insight from a Literature Review *Journal of Quantity Surveying and Construction Business*. 7 (1): pp.31-54.



- Rajasekar, S., Philominathan, P. and Chinnathambi, V. (2006). Research methodology. *arXiv preprint physics/0601009*.
- Reddy, K. P. (2011). *BIM for Building Owners and Developers: Making a Business Case for using BIM on Projects*: John Wiley & Sons.
- Ren, Y., Skibniewski, M. J. and Jiang, S. (2012). Building information modeling integrated with electronic commerce material procurement and supplier performance management system. *Journal of Civil Engineering and Management*. 18(5): pp.642-654.
- Rogers, J., Chong, H.-Y. and Preece, C. (2015). Adoption of Building Information Modelling technology (BIM) Perspectives from Malaysian engineering consulting services firms. *Engineering, Construction and Architectural Management*. 22(4): pp.424-445.
- Rosenburg, T. (2007). *Building Information Modeling*. Retrieved on January 10, 2014 from: <http://www.ralaw.com/resources/documents/Building%20Information%20Modeling>.
- Rowlinson, S. (2017). Building Information Modelling, Integrated Project Delivery and All That. *Construction Innovation*. 17(1): pp.45-49.
- Sackey, E., Tuuli, M. and Dainty, A. (2013). BIM Implementation: From Capability Maturity Models to Implementation Strategy. *Paper presented at the Sustainable Building Conference 2013*.
- Sackey, E., Tuuli, M. and Dainty, A. (2014). Sociotechnical Systems Approach to BIM Implementation in a Multidisciplinary Construction Context. *Journal of management in engineering*. 31(1): pp.A4014005.
- Sacks, R., Gurevich, U. and Shrestha, P. (2016). A review of building information modeling protocols, guides and standards for large construction clients. *Journal of Information Technology in Construction (ITcon)*. 21(29): pp.479-503.
- Saunders, M. N. K., Lewis, P. and Thornhill, A. (2015). *Research Methods for Business Students*: Pearson Education Limited.
- Sebastian, R. and van Berlo, L. (2010). Tool for Benchmarking BIM Performance of Design, Engineering and Construction Firms in the Netherlands. *Architectural Engineering and Design Management*. 6(4): pp.254-263.
- Serenko, A., Bontis, N. and Hull, E. (2014). An application of the knowledge management maturity model: the case of credit unions.
- Shehu, Z., Endut, I. R. and Akintoye, A. (2014). Factors contributing to project time and hence cost overrun in the Malaysian construction industry. *Journal of Financial Management of Property and Construction*. 19(1): pp.55-75.
- Shen, L., Edirisinghe, R. and Yang, M. (2016) An investigation of BIM readiness of owners and facility managers in Singapore: Institutional case study. *Paper presented at the CIB World Building Congress*.
- Shou, W. C., Wang, J., Wang, X. Y. and Chong, H. Y. (2015). A Comparative Review of Building Information Modelling Implementation in Building and Infrastructure Industries. *Archives of Computational Methods in Engineering*. 22(2): pp.291-308.
- Sinclair, M. (2012). *BIM Overlay to the RIBA Outline Plan of Work*. Retrieved January 10, 2016, from: file:///C:/Users/User/Downloads/BIMOverlaytotheRIBAOutlinePlanofWorkpdf%20(3).pdf
- Sinesilassie, E., Tabish, S. and Jha, K. (2017). Critical factors affecting cost performance: a case of Ethiopian public construction projects. *International Journal of Construction Management*: pp.1-12.

- Smith, P. (2014a). BIM & the 5D project cost manager. *Procedia-Social and Behavioral Sciences*. 119: pp.475-484.
- Smith, P. (2014b) BIM implementation—global initiatives & creative approaches. *Paper presented at the CC2014 Creative Construction Conference*. Diamond Congress Pty Ltd.
- Smits, W., van Buiten, M. and Hartmann, T. (2017). Yield-to-BIM: impacts of BIM maturity on project performance. *Building Research & Information*. 45(3): pp.336-346.
- Stahl, F. I., Wright, R. N., Fenves, S. J. and R Harris, J. (1983). Expressing Standards for Computer-Aided Building Design. *Computer-aided design*. Vol. 15(6): pp.329-334.
- Stanley, R. and Thurnell, D. (2014). The benefits of, and barriers to, implementation of 5D BIM for quantity surveying in New Zealand.
- Succar, B. (2009a). Building Information Modelling Framework: A Research and Delivery Foundation for Industry Stakeholders. *Automation in Construction*. vol. 18(3): pp.357-375.
- Succar, B. (2009b). Building information modelling maturity matrix. *Handbook of Research on Building Information Modeling and Construction Informatics: Concepts and Technologies*, IGI Global: pp.65-103.
- Succar, B. and Kassem, M. (2015). Macro-BIM adoption: Conceptual structures. *Automation in Construction*. 57: pp.64-79.
- Sun, C., Jiang, S., Skibniewski, M. J., Man, Q. and Shen, L. (2017). A literature review of the factors limiting the application of BIM in the construction industry. *Technological and Economic Development of Economy*. 23(5): pp.764-779.
- Taihairan, R. B. R. and Ismail, Z. (2015). BIM: Integrating Cost Estimates at Initial/Design Stage. *International Journal of Sustainable Construction Engineering and Technology*. 6(1): pp.62-74.
- Talebi, S. (2014). Rethinking the project development process through use of BIM. *Paper presented at the 2nd BIM International Conference on Challenges to Overcome*. BIMForum Portugal.
- Taylor, J. E. and Bernstein, P. G. (2009). Paradigm trajectories of building information modeling practice in project networks. *Journal of Management in Engineering*. 25(2): pp.69-76.
- Underwood, J., Chomeniuk, J., Brady, L. and Woodcock, D. (2016). Manchester Central Library and Town Hall Extension Project: the BIM journey so far of a public sector client.
- Vaidyanathan, K. and Howell, G. (2007). Construction supply chain maturity model—conceptual framework. *Paper presented at the Proceedings IGLC*. pp. 170-180.
- Venkatachalam, S. (2017). An exploratory study on the building information modeling adoption in United Arab Emirates municipal projects—current status and challenges. *Paper presented at the MATEC Web of Conferences*. EDP Sciences. pp. 02015.
- Wang, Y., Wang, X., Wang, J., Yung, P. and Jun, G. (2013). Engagement of facilities management in design stage through BIM: framework and a case study. *Advances in Civil Engineering*. 2013.
- Weygant, R. S. (2011). *BIM Content Development: Standards, Strategies, and Best Practices*: Wiley.

- Wong, A., Wong, F. K. and Nadeem, A. (2009) Comparative roles of major stakeholders for the implementation of BIM in various countries. *Paper presented at the Proceedings of the International Conference on Changing Roles: New Roles, New Challenges, Noordwijk Aan Zee, The Netherlands*. pp. 5-9.
- Wong, A. K., Wong, F. K. and Nadeem, A. (2010). Attributes of Building Information Modelling Implementations in Various Countries. *Architectural Engineering and Design Management*. 6(4): pp.288-302.
- Wu, C., Xu, B., Mao, C. and Li, X. (2017). Overview of BIM Maturity Measurement Tools. *Journal of Information Technology in Construction (ITcon)*. 22(3): pp.34-62.
- Wu, S., Wood, G., Ginige, K. and Jong, S. (2014). A Technical Review of BIM Based Cost Estimating in UK Quantity Surveying Practice, Standards and Tools. *Journal of Information Technology in Construction (ITCon)*. 19: pp.534-562.
- Yan, H. and Demian, P. (2008). Benefits and Barriers of Building Information Modelling. *Paper presented at the Proceedings of the 12th International Conference on Computing in Civil and Building Engineering (ICCCBE XII) & 2008 International Conference on Information Technology in Construction (INCITE 2008)*, Beijing, China. Tingshua University Press.
- Yap, J. B. H., Abdul-Rahman, H. and Chen, W. (2017). Collaborative Model: Managing Design Changes with Reusable Project Experiences through Project Learning and Effective Communication. *International Journal of Project Management*. 35(7): pp.1253-1271.
- Yousefzadeh, S., Spillane, J. P., Lamont, L., McFadden, J. and Lim, J. (2015). Building Information Modelling (BIM) Software Interoperability: A Review of the Construction Sector. *Proceedings of the 31st Annual ARCOM Conference*. pp. 711-720.
- Zainon, N., Mohd-Rahim, F. A. and Salleh, H. (2016). The Rise Of BIM in Malaysia And Its Impact Towards Quantity Surveying Practices. *Paper presented at the MATEC Web of Conferences*. EDP Sciences. pp. 00060.
- Zakaria, Z., Mohamed Ali, N., Tarmizi Haron, A., Marshall-Ponting, A. and Abd Hamid, Z. (2013). Exploring The Adoption of Building Information Modelling (BIM) in the Malaysian Construction Industry: A Qualitative Approach. *International Journal of Research in Engineering and Technology*. 2(8): pp.384-395.
- Zhao, X., Pienaar, J. and Gao, S. (2018). Critical Risks Associated with BIM Adoption: A Case of Singapore. *Paper presented at the Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*. Springer. pp. 585-596.
- Zikmund, W. G., Babin, B. J., Carr, J. C. and Griffin, M. (2013). *Business Research Methods*: Cengage Learning.
- Zuhairi, A. H., Marshall-Ponting, A., Ahmad, T. H., Nasly, M. A. and Zahrizan, Z. (2014). Exploring the barriers and driving factors in implementing building Information Modelling (BIM) in the malaysian construction industry-a preliminary study.